Publication 1652-03-10-1712

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DESTROYER ENGINEERED OPERATING CYCLE (DDEOC)

System Maintenance Analysis

DDG-37 CLASS FIREMAIN AND AUXILIARY MACHINERY COOLING WATER SYSTEMS

SMA 37-201-521

REVIEW OF EXPERIENCE

February 1978

Prepared for
Director, Escort and Cruiser
Ship Logistic Division
Naval Sea Systems Command
Washington, D. C.
under Contract N00024-78-C-4062

ARINC RESEARCH CORPORATION

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 1652-03-10-1715	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DDEOC System Maintenance Analysis DDG-37 Class Firemain and Auxiliary Machinery Cooling Water Systems SMA 37-201-521		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER 1652-03-10-1715
7. AUTHOR(s) F. P. Lounsberry		8. CONTRACT OR GRANT NUMBER(s) N00024-78-C-4062
9. PERFORMING ORGANIZATION NAME AND ADDRESS ARINC Research Corp. 2551 Riva Road Annapolis, Maryland 21401		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Director, Escort and Cruiser Ship Logistic Division Naval Sea Systems Command Washington, D.C.		12. REPORT DATE February 1978
		13. NUMBER OF PAGES 46
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Director, Escort and Cruiser Ship Logistic Division Naval Sea Systems Command Washington, D.C.		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

UNCLASSIFIED/UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Ent

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by

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Publication 1652-03-10-1715 14

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FOREWORD

This report, the Review of Experience, documents the historical maintenance experience for the DDG-37 Class Firemain and Auxiliary Machinery Cooling Water Systems, presents an analysis of the problems encountered, and recommends actions to improve system material condition. It has been developed for NAVSEA 934X, the sponsor of the Destroyer Engineered Operating Cycle (DDEOC) Program, under Navy Contract N00024-78-C-4062.

SUMMARY

The goal of the Destroyer Engineered Operating Cycle (DDEOC) Program is to effect an early improvement in the material condition of ships, at an acceptable cost, while maintaining or increasing their operational availability during an extended operating cycle. In support of this goal, System Maintenance Analyses (SMAs) are being conducted for selected systems and subsystems of designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the DDG-37 Class Firemain and Auxiliary Machinery Cooling Water Systems.

The ROE is an analysis of existing and anticipated problems that affect the operational performance or maintenance program of a ship system. The ROE report serves as a vehicle for assessing the significance and consequences of identified problems. The report also recommends specific actions and a system maintenance policy that will prevent or reduce the impact of problem occurrence while improving material condition and maintaining or increasing system availability throughout an extended ship operating cycle.

The Firemain and Auxiliary Machinery Cooling Water Systems ROE includes an analysis of all available maintenance data sources. The documented maintenance experience of the system was reviewed through analysis of data from the Maintenance Data System (MDS), Casualty Reports (CASREPs), and system overhaul records. Initial findings from these sources were correlated with Planned Maintenance System (PMS) requirements, system alterations, and system technical manuals to identify maintenance problems. Ship surveys were conducted and discussions were held with appropriate technical groups to validate identified problem areas, identify undocumented maintenance problems, and determine the status of current and planned actions affecting the Firemain and Auxiliary Machinery Cooling Water Systems. All findings were evaluated and appropriate conclusions developed. Recommendations were then formulated to implement existing and newly defined corrective actions to minimize the occurrence of identified maintenance problems and their impact on an extended operating cycle.

The major findings and conclusions resulting from the Review of Experience for the Firemain and Auxiliary Machinery Cooling Water Systems are summarized as follows:

- Major restorative maintenance of the Firemain and Auxiliary Machinery Cooling Water Systems, with the exception of the firepump turbines and pressure regulators, will not be required during Baseline Overhaul (BOH) or during the Engineered Operating Cycle.
- The firepump turbines and pressure regulators require a Class "B" overhaul during BOH and at each follow-on ROH.
- Ship's Force is normally capable of maintaining the system with Intermediate Maintenance Activity (IMA) assistance.
- The Ship's Force repair effort is generally hindered by the lack of:
  - An adequately maintained lathe
  - A comprehensive standard procedure for centrifugal pump overhaul
- Incorporation of the sealed insulation system for electric motor rewinds promises to be an excellent long-term solution to the high rewind rate for electric motors.
- The impeller wearing rings for the cast gun-metal casing firepumps currently stocked in the Navy Supply System are not suited for salt water applications.
- The Firemain and Auxiliary Machinery Cooling Water Systems appear to be adequately supported by the Navy Supply System; only one major change is necessary.
- Current PMS requirements, as modified by changes recommended in this report, are adequate to maintain the Firemain and Auxiliary Machinery Cooling Water Systems throughout the Engineered Operating Cycle.

Reliable operation of the Firemain and Auxiliary Machinery Cooling Water Systems can be expected during the Engineered Operating Cycle if several recommended changes are performed in the following areas:

- Baseline Overhaul (BOH) Requirements
- Intracycle Maintenance Requirements
- Follow-On ROH Requirements
- Reliability and Maintainability Improvements
- Planned Maintenance System Changes
- Industrial Facility Improvements
- IMA Improvements
- Integrated Logistic Support (ILS) Improvements

Table S-1 summarizes all recommendations resulting from this Review of Experience.

Table S-1. SUMMARY OF ROE RECOMMENDATIONS		
Equipment	Recommendation	Reason
Baseline Overhaul Requirements		
Engine Lathe	Inspect and repair as necessary.	Availability of a workable lathe is fundamental to the Ship's Force repair effort.
	Ensure that all attachments are available.	
Firepump Turbine	Perform Class "B" overhaul of the turbines in accordance with TRS 0521-086-601.	This type of overhaul should be accomplished only at the depot level.
Intracycle Maintenance Requirements		
All equipments of the Firemain and Auxiliary Machinery Cooling Water Systems	Accomplish existing PMS requirements as modified by recommendations of this report.	Existing PMS requirements, modified as recommended by this report, adequately address required intracycle maintenance.
Follow-On ROH Requirements		
Engine Lathe	Inspect and repair as necessary.	Availability of a workable lathe is fundamental to the Ship's Force repair effort.
Firepump Turbines	Perform Class "B" overhaul of the turbines in accordance with TRS 0521-096-601.	Estimated to be necessary by the end of a 60-month operating cycle.
Reliability and Maintainability Improvements		
Motor and Turbine Driven Firepumps	TYCOM should establish a uniform firepump operating policy to: • Operate firepumps 2 and 4 whenever steam is available. • Operate firepumps 1 and 6 in port or when under way when firepumps 2 and 4 are not available. • Keep firepumps 3 and 5 set up for automatic start to the maximum extent possible.	Shift the relative maintenance burden from the high-burdened 3 and 5 to the lower-burdened 1 and 6, reduce the number of rewinds of 1 and 6, and increase the effectiveness of the automatic start capability of 3 and 5.
	NAVSEC should determine the best method for gun-metal pump casing repair and promulgate uniform repair instructions.	At least two different methods of repair are currently in use, no determination having been made of which method is preferred.
	Use a run-to-failure maintenance strategy for the installed firepumps of the DDG-37 Class.	The mean time between significant maintenance actions is short.
	Develop a ShipAlt to implement the recommended relocation of the firepump bearing housing vent drain.	Improved grease flow through the bearing.
	Develop a ShipAlt to install stainless steel casings on all DDG-37 Class firepumps.	Stainless steel casings provide a solution to the casing erosion problems, and firepumps 3 and 5 have more casing erosion problems than other firepumps.

(continued)

Table S-1. (continued)		
Equipment	**Recommendation**	**Reason**
Reliability and Maintainability Improvements (continued)		
Firepump Electric Motors	Use a run-to-failure maintenance strategy for the installed firepump electric motors.	Motor-rewind prevention does not lend itself well to preventive maintenance based on calendar time.
	Develop a procedure to rewind the electric motors utilizing the sealed insulation system on all four electric-motor-driven firepumps.	The sealed insulation system, when implemented, promises to be an excellent long-term solution to the high rate of electric motor rewind for motors subjected to high-moisture environment.
Firepump Turbine	Use a run-to-failure maintenance strategy for the installed firepump turbines.	The intracycle maintenance should be minor, with major corrective maintenance being accomplished at BOH and follow-on ROHs.
Auxiliary Machinery Cooling Water Pump	Have Ship's Force check the flange-to-flange alignment of the pump and suction and discharge piping and adjust the pump foundation bolts and the piping hangers to correct any misalignment. The check should be made each time this pump is opened for corrective maintenance.	Reduce the internal wearing parts and motor bearing usage rates.
	Use a run-to-failure maintenance strategy for the installed auxiliary machinery cooling water pumps.	The mean time between significant maintenance actions is short.
	Develop a ShipAlt to provide a mechanical seal for the pump.	Decrease the number of motor rewinds.
Auxiliary Machinery Cooling Water Pump Motor	Construct a shield of light sheet metal over the motor.	Prevent grounding out of the motor due to accidental wetting.
	Develop a procedure to rewind the electric motors utilizing the sealed insulation system on both motors.	The sealed insulation system, when implemented, promises to be an excellent long-term solution to the high rate of electric motor rewind for motors subjected to high-moisture environments.
	Planned Maintenance System Changes	
Motor and Turbine Driven Firepumps	Change the periodicity of the annual open and inspect PMS check to a situation requirement.	The pump internals will be inspected when opened for corrective maintenance.
Motor Driven Firepumps	Establish a PMS requirement to operate firepumps 1 and 6 every day for about one hour.	Moisture accumulation will be prevented and the number of motor rewinds reduced.

(continued)

Table S-1. (continued)		
Equipment	Recommendation	Reason
Planned Maintenance System Changes (continued)		
Swing Check Valve	Establish a monthly PMS requirement to open and inspect firepump swing check valves on turbine driven firepumps.	Failure of the swing check valve usually results in serious damage to the motor or turbine.
Auxiliary Machinery Cooling Water Pumps	Change the periodicity of the annual open and inspect PMS check to a situation requirement.	The pump internals will be inspected when opened for corrective maintenance.
Industrial Facility Improvements		
None		
IMA Improvements		
None		
Integrated Logistic Support (ILS) Requirements		
Engine Lathe	Have individual ships take the necessary steps to ensure that the assigned lathe operators are qualified in the operation and maintenance of the equipment.	A workable lathe with a qualified operator is fundamental to the Ship's Force repair effort.
	Provide DDG-39 with a lathe capable of accommodating the impeller diameter of the largest installed centrifugal pump.	A lathe with a minimum 10" swing is required.
Centrifugal Pump	Provide Ship's Force with a suitable Centrifugal Pump Repair Manual.	The organizational level maintenance effort will be improved.
	Provide suitable ball bearing heater ovens.	Ball bearing removal and reinstallation procedures will be standardized.
Motor and Turbine Driven Firepump	Provide APL 016021445 to all ships with stainless steel pumps and ensure that shipboard allowances for spare parts are adequate.	Ship visits indicated that ships with stainless steel pumps did not have the correct APLs.
	Change the material requirements for the impeller wearing rings of the firepumps supported by APL 016020494 from Stainless Steel class 303 to monel, QQ-N-288, composition B or D.	Currently stocked impeller wearing ring is not suitable for salt water applications.
	Assign an NSN to the monel impeller wearing ring, and revise APL 016020494 accordingly.	A monel impeller wearing ring will be less subject to corrosion than the currently stocked stainless steel one.
Firepump Swing Check Valve	Conduct a COSAL validation to ensure that the installed firepump swing check valves are supported by the proper APL.	Present COSALs do not always include the installed swing check valves.
Auxiliary Machinery Cooling Water Pump	Add NSN 9C-4320-00-541-8843, impeller wearing ring, to APL 016110076, with an allowance for two on-board spares.	The impeller wearing ring is not listed on the APL for the pump.

CONTENTS

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

In support of the Destroyer Engineered Operating Cycle (DDEOC) Program, sponsored by NAVSEA 934X, System Maintenance Analyses (SMAs) are being conducted on selected systems and subsystems of program-designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the DDG-37 Class Firemain and Auxiliary Machinery Cooling Water Systems, which were specifically selected for analysis because equipments of those systems are on the DDG-37 Class Maintenance Critical Equipment List.

1.2 PURPOSE AND SCOPE

The ROE is an analysis of existing and anticipated problems that affect the operational performance or maintenance program of a ship system. The ROE report serves as a vehicle for assessing the significance and consequences of identified maintenance problems. It also presents specific recommendations and a system maintenance policy that will prevent or reduce the impact of problems while improving material condition and maintaining or increasing system availability through an extended ship operating cycle.

The analysis documented herein is specifically applicable to the Firemain and Auxiliary Machinery Cooling Water Systems installed on the DDG-37 Class. Only those system components that had been installed or were on board ship as of the fourth quarter of Fiscal Year 1976 were considered. The analysis used all available documented data sources from which system maintenance problems could be identified and studied. These included Maintenance Data System (MDS) data, Casualty Reports (CASREPs), and system overhaul records, in addition to Planned Maintenance System (PMS) requirements data, system alteration documentation, and system technical manuals. Sources of undocumented data employed in this analysis included discussions with Ship's Force and other cognizant technical personnel.

1.3 SYSTEM FUNCTION AND BOUNDARIES

The Firemain System on the DDG-37 Class supplies sea water at 125 psig for the firemain, magazine sprinkling system, flushing system and decontamination stations in the ship's heads, main and secondary eductors, ballasting and deballasting system, and emergency cooling for various electronic and auxiliary machinery cooling systems. In this analysis only those components of the Firemain System which were significant contributors to the overall system maintenance burden were considered. Appendix A shows a typical DDG-37 Firemain System (Figure A-1) and lists the components that were identified for analysis (Table A-1). The individual systems serviced by the firemain were not subjected to detailed analysis since they are part of separate systems not addressed by this ROE.

The Auxiliary Machinery Cooling Water System on the DDG-37 Class supplies sea water at 50 psig for various steam-driven auxiliary machinery lube oil coolers; air compressor air coolers; auxiliary gland leak-off condensers; boiler water sample coolers; and cooling, lubricating, and flushing of the stern tube bearing. In this analysis only those components of the Auxiliary Machinery Cooling Water System which were significant contributors to the maintenance burden were considered. Figure A-1 of Appendix A includes a diagram of a typical DDG-37 Auxiliary Machinery Cooling Water System. It also shows the interface between the two systems under study and the emergency supply from the firemain to the auxiliary machinery cooling water main. The individual heat exchangers for particular equipments that are cooled by the system are not included in this ROE but are covered in the ROE for the specific equipment involved.

1.4 REPORT FORMAT

The remaining chapters of this report describe the analysis approach utilized (Chapter Two), briefly define significant system maintenance problems encountered and discuss potential problem solutions (Chapter Three), and summarize conclusions and recommendations derived from the analysis (Chapter Four). Specific analyses and evaluations supporting the results of this effort and included as appendixes to this report. A selected list of references precedes the appendixes.

CHAPTER TWO

APPROACH

Primary data sources used in performing the ROE for the Firemain and Auxiliary Machinery Cooling Water Systems are identified in Section 1.2. The data were used to identify, define, and analyze maintenance problems that will significantly affect the systems' maintenance program. A recommended course of action relative to the maintenance program was formulated on the basis of the analysis results.

The analysis began at the component level at which Allowance Parts List (APL) numbers are assigned. It comprised the following major steps as described in Sections 2.1 through 2.3:

- Compiling relevant documented and undocumented maintenance history data
- Analyzing these data to identify and define maintenance problems expected to have significant impact on maintenance of the systems
- Recommending a specific course of action for solution of the system maintenance problems

2.1 DATA COMPILATION

The analysis began with the compilation of data on the maintenance history of the systems. The data file generated consisted of four key elements: an MDS data bank, a CASREP narrative summary, a system overhaul experience summary, and a system shipAlt summary. A library of appropriate technical manuals, bulletins, etc., was also compiled. All MDS data reported for the DDG-37 Class from 1 January 1970 through 31 October 1976 were screened for information pertinent to the system. Overhaul experience was obtained from Mechanized Departure Reports for the DDG-37 Class. Continued reference was made to all of the noted sources throughout the analysis.

2.2 MAINTENANCE PROBLEM DEFINITION

Potential maintenance problems associated with the systems and their components were identified by a screening process employing data obtained

from the above-described sources as well as from ship surveys, discussions with Navy technical personnel, and, when appropriate, NAVSEA special interest items.

MDS data constitute the initial and primary source of information used in the screening process. This data base includes all part and labor records, as well as narrative material, describing maintenance actions reported against system components. Maintenance actions are represented by Job Control Numbers (JCN). The purpose of the first step in the screening process was to identify the maintenance actions that had been reported against components of the systems under investigation.

Computer-assisted analysis was next employed to quantify the man-hour and part-expenditure burdens incurred for each component. These calculations were performed not only for the selected components individually but also, as appropriate, for each generic class of components. Individual components or component classes that had contributed significantly to the systems' maintenance burden were selected for the analysis described below. Components were also selected for this purpose if they had generated a significant number of CASREPs or if other sources of information (e.g., ship surveys or overhaul experience) disclosed significant concern regarding maintenance problems or the maintenance programs for the components.

Detailed analysis of the selected components was directed toward defining each maintenance problem in terms of several specific factors: the effect of the problem on the component and system; the interval between occurrences of the problem, the redundancy of the affected component within the system, the criticality of the component to the system, the resources required to perform the maintenance necessary to correct the problem, and the expected component or system downtime.

2.3 ANALYSIS OF COMPONENT MAINTENANCE PROBLEMS AND DEFINITION OF SOLUTIONS

Once the component problems and the causes of the problems were identified, solutions were sought by examining each problem in relation to the extent to which it is recognized and its susceptibility to established types of corrective action. These analysis criteria can be expressed by the following questions:

- Is the problem known to the Navy technical community and has a solution been proposed or established?
- Will a design change reduce or eliminate the problem?
- Is the problem PMS-related? Can the problem be reduced or eliminated by changes to PMS? (These changes might include adding or deleting requirements, changing periodicity, or developing material condition assessment tests and procedures.)

- Can the problem be reduced or eliminated by improving Ship's Force, Intermediate Maintenance Activity (IMA), or depot-level capabilities?
- Can the problem be reduced or eliminated by periodically performing restorative maintenance? Should this be accomplished at a Selected Restricted Availability (SRA) by Ship's Force, IMA, or depot-level facilities?
- Is the run-to-failure concept a viable maintenance strategy for the associated equipment.

An affirmative answer to any question resulted in analysis of the effects of the solution and in an estimate, when possible, of the cost to implement the solution. A negative answer prompted the analyst to go to the next question.

The historical overhaul experience for all installations of each selected component was then correlated with the recommended problem solutions. An evaluation was made to establish the Baseline Overhaul, intra-cycle, and follow-on Regular Overhaul requirements for each selected component.

CHAPTER THREE

ANALYSIS RESULTS

3.1 OVERVIEW

Preliminary analysis of the MDS data resulted in the identification of 10 system components that warranted detailed analysis. The MDS maintenance burden data for these components are summarized in Table 3-1.

A review of part replacement histories identified those replacement parts within the selected components requiring further analysis. Pertinent data for these parts are summarized in Table 3-2. CASREP analysis supported the MDS data analysis performed to define repetitive or significant maintenance actions. Appendix B summarizes the CASREPs reported against the equipments of the Firemain System and indicates the percentage of total system CASREPs attributed to each equipment, as well as the types of failures experienced. Ship surveys and discussions with Navy technical code personnel confirmed the existence of maintenance problems disclosed by the analysis and identified a supply support problem related to wearing ring material.

The following 10 system components were subjected to detailed analysis because of significant intracycle maintenance experience:

- Firemain System
  - Firepump (APL 016020494)
  - Firepump (APL 016020528)
  - Firepump Motor (APL 174750564)
  - Firepump Turbine (APL 057950042)
  - Firepump Turbine Regulator (APL 882260195)
  - Firepump Turbine Regulator (APL 882260469)
  - Flexible Coupling (APL 782350005)
  - 4.0" IPS Swing Check Valve (APL 882035712)
- Auxiliary Machinery Cooling Water System
  - Auxiliary Machinery Cooling Water Pump (APL 016110076)
  - Auxiliary Machinery Cooling Water Pump Motor (APL 174750217)

Table 3-1. COMPONENT BURDENS OF DDG-37 CLASS FIREMAIN AND AUXILIARY MACHINERY COOLING WATER SYSTEMS

APL	Nomenclature	Applicable Ships	Components per Ship	Total Component Population	Total Ship Operating Time (Ship-Years)	Ships Reported	JCNs	Ship's Force Man-Hours	IMA Man-Hours	Total Man-Hours	Parts Cost (Dollars)	Average Man-Hours/ Component Operating Year
					Firemain System							
016020494*	Firepump, 500 G.P.M.	10	6**	59**	51.9	10	786	7,723	7,623	15,346	148,967	52.3
016020528	Firepump, 500 G.P.M.	1(2)	1†	1†	5.8	1	6	157	6	163	1,526	28.1
174750564	Firepump Motor	10	4	40	51.9	10	173	3,697	4,025	7,722	8,074	37.2
057950042	Firepump Turbine	10	2	20	51.9	10	260	4,606	1,965	6,571	30,598	63.3
882260195	Firepump Turbine Regulator	9	2	18	47.5	9	56	219	144	363	2,893	3.8
882260469	Firepump Turbine Regulator	1	2	2	4.4	1	19	120	38	158	3,378	18.0
782350005	Flexible Coupling	10	6	60	51.9	10	53	546	72	618	9,953	2.0
882035712	4.0" IPS Swing Check Valve	5	Various	26	25.8	5	8	24	26	50	919	0.3
						Subtotal	1361	17,092	13,899	30,991	206,308	
					Auxiliary Machinery Cooling Water System							
016110076	Auxiliary Machinery Cooling Waterpump	10	2	20	51.9	10	177	1,752	1,017	2,769	10,331	26.7
174750217	Auxiliary Machinery Cooling Waterpump Motor	10	2	20	51.9	10	123	2,103	1,358	3,461	9,913	33.3
						Subtotal	300	3,855	2,375	6,230	20,244	
						Grand Totals	1,661	20,947	16,274	37,221	226,552	
						Total Reported for All System APLs	2,355	25,333	21,514	46,847	276,757	
						Percent of Total Accounted for by Selected APLs	71	83	76	79	82	

*This APL also includes data that should have been reported against APL 016021445 (see text, Section 3.2.1).
**All ships of the class are equipped with 6 except DDG-44, which has 5. This accounts for a total population of 59 vs. 60.
†DDG-44 is equipped with one firepump covered by APL 016020528. It is identical to the other 59 pumps of the class covered by APL 016021445 (see text, Section 3.2.1).

Table 3-2. PARTS USAGE SUMMARY FOR SELECTED COMPONENTS OF DDG-37 CLASS FIREMAIN AND AUXILIARY MACHINERY COOLING WATER SYSTEMS

Part Identification		Current Cost per Unit (Dollars)	Quantity per Component	Total Part Population	Number Replaced	Ratio (x 100) of Parts Replaced to Total Population	Number of Ships Reported
NSN	Nomenclature						
Firemain System							
Firepump, APL 016020494/016020528							
9Z 3110-00-864-0575	Thrust Bearing	29.74	1	60	225	375	10
9Z 3110-00-155-6160	Bearing	5.54	1	60	219	365	10
9C 4320-00-541-9065[1]	Impeller Wearing Ring	6.88	2	120	196	163	10
9C 4320-00-541-9064[2]	Casing Wearing Ring	17.99	2	120	225	188	10
9C 4320-00-479-8862	Impeller Wearing Ring	22.15	2	120	73	61	9
9C 4320-00-479-0861	Casing Wearing Ring	91.52	2	120	50	42	9
9C 4320-00-493-2013	Rotor Assembly	6907.68	1	60	12	20	6
9C 4320-00-625-6917	Sleeve	87.94	1	60	138	230	10
9C 4320-00-625-6918	Sleeve	101.92	1	60	150	250	10
9C 4320-00-541-9061	Deflector	12.58	2	120	29	24	10
1HM4320-00-766-8010	Shaft	588.00	1	60	225	375	10
Firepump Motor, APL 174750564							
9Z 3110-00-155-6266[3]	Bearing	7.18	1	40	139	348	10
9Z 3110-00-155-6302[3]	Bearing	15.81	1	40	119	298	10
Firepump Turbine, APL 057950042							
1HM2825-00-097-1710	Carbon Packing	7.40	8	160	214	134	10
1HM2825-00-383-6730	Shaft Bearing Assembly	39.00	2	40	53	133	9
1HM2825-00-383-6731	Bearing Oil Seal	37.50	3	60	18	30	6
Firepump Turbine Regulator, APL 882260195							
9C 4820-00-446-3403	Diaphragm	26.08	1	8	28	350	9
9C 4820-00-036-1526	Needle Valve Assembly	9.19	1	18	12	67	7
9C 4820-00-036-1516	Valve Piston	33.38	1	18	3	17	3
9C 4820-00-280-1229	Piston Ring	4.25	2	36	22	61	5
Firepump Turbine Regulator, APL 882260469							
9C 4820-00-446-3403	Diaphragm	26.08	1	2	6	300	1
9C 4820-00-036-1516	Valve Piston	33.38	1	2	7	350	1
9C 4820-00-288-1229	Piston Ring	4.25	2	4	19	475	1
2H 4320-00-023-6280	Regulator	2030.00	1	2	1	50	1
9C 4820-00-036-1532	Main Valve Disc	29.10	1	2	4	200	1
Flexible Coupling, APL 782350005							
9C 3010-00-239-3440	Flexible Coupling	109.20	1	60	36	60	8
4.0" IPS Swing Check Valve, APL 882035712							
1H 4820-00-086-9540	Check Valve	283.00	1	30	3	10	2

[1]This NSN was replaced by NSN 9C 4320-00-479-8862, effective 2/73 (see Table 3-6).
[2]This NSN was replaced by NSN 9C 4320-00-479-8861, effective 2/73 (see Table 3-6).
[3]This NSN is listed on APL 174750564 dated 08/08/74 but not on the same APL dated 03/01/76 (see Section 3.2.3.4).

(continued)

Table 3-2. (continued)							
Part Identification		Current Cost per Unit (Dollars)	Quantity per Component	Total Part Population	Number Replaced	Ratio (× 100) of Parts Replaced to Total Population	Number of Ships Reported
NSN	Nomenclature						
Auxiliary Machinery Cooling Water System							
Auxiliary Machinery Cooling Water Pump, APL 016110076							
9C 4320-00-541-8843[a]	Impeller Wearing Ring	6.41	2	20	97	485	10
9C 4320-00-541-8842	Casing Wearing Ring	9.58	2	20	106	530	10
9C 4320-00-393-3486	Sleeve	36.61	1	20	28	140	10
9C 4320-00-119-3368	Deflector	8.78	1	20	15	75	9
1HM4320-00-625-3848	Impeller	459.00	1	20	11	55	7
Auxiliary Machinery Cooling Water Pump Motor, APL 174750217							
9Z 3110-00-155-6282	Bearing	10.26	1	20	105	525	10
9Z 3110-00-155-6302	Bearing	15.81	1	20	106	530	10
2HH6105-00-284-1771	Rotor	1060.00	1	20	4	20	3
2HH6105-00-500-3444	Stator	3022.00	1	20	1	5	1

[a]Currently not listed on the APL (see Section 3.3.1.3).

The firepump supported by APL 016020528 is identical to the firepump supported by APL 016020494 except that its discharge flange is 1" thick rather than 5/8" thick. Therefore, in this ROE all MDS data for the firepump supported by APL 016020528 have been included with APL 016020494. These systems and their respective selected components are discussed in detail in the following sections of this chapter.

3.1.1 Maintenance Support

Several problems related to the maintenance support of the Firemain and Auxiliary Machinery Cooling Water Systems were identified. Since these problems also have an impact on other DDG-37 Class systems, they are discussed below. The recommendations made will resolve similar support problems for all affected systems.

3.1.1.1 Engine Lathes Installed on DDG-37 Class Ships

An operable lathe, complete with attachments, and a qualified operator are essential to centrifugal pump maintenance at the organizational level. Ship visits and discussions with NAVSEC codes indicated that on the typical DDG-37 Class ship the installed lathe did not have all its attachments and was not in good working order, and only one qualified operator was on board.

Table 3-3 lists the lathes currently installed on the DDG-37 Class ships.

The APLs for the lathes listed in Table 3-3 indicate that the lathes are furnished complete with all attachments except cutters and tool bits, which are furnished by AEL 1-911154261. This AEL is applicable to all DDG-37 Class ships.

Table 3-3. ENGINE LATHES INSTALLED ON DDG-37 CLASS SHIPS			
Hull Number	Lathe APL	Swing	Manufacturer
DDG-37	410350001	16.5"	Springfield Machine Tool Company
DDG-38	410350001	16.5"	Springfield Machine Tool Company
DDG-39	410470057	8.5"	Lodge and Shipley Company
DDG-40	410830027	15.0"	Sheldon Machine Company
DDG-41	410320084	17.0"	Amsted Industries Inc., South Bend Lathe Division
DDG-42	410350001	16.5"	Springfield Machine Tool Company
DDG-43	410980003	13.0"	LeBlond, Inc.
DDG-44	410830027	15.0"	Sheldon Machine Company
DDG-45	410350001	16.5"	Springfield Machine Tool Company
DDG-46	410830026	15.0"	Sheldon Machine Company

A review of the centrifugal pumps installed on DDG-37 Class ships revealed that the two-stage main condensate and main feed booster pump rotors have the largest-diameter impellers, at 18.5" and 14.5", respectively. Therefore, the largest swing (radius) required to machine all centrifugal pumps, including firepumps and Auxiliary Machinery Cooling Water Pumps, on the DDG-37 Class would be one-half of 18.5", or approximately 10" with an allowance for lathe clearance. As shown in Table 3-3, all DDG-37 Class ships except DDG-39 have lathes with swings in excess of 10". DDG-39 could turn all installed centrifugal pump rotors except the main condensate pump rotors, while all the other DDG-37 Class ships could turn all installed centrifugal pump rotors.

The capability to turn a centrifugal pump rotor is necessary for the proper replacement and cutting to size of the impeller wearing rings on centrifugal pumps. Casing wearing rings are normally smaller than the impeller of the same centrifugal pump. Therefore, the impeller diameter determines the minimum swing required of a ship's lathe.

The following specific maintenance actions applicable to centrifugal pumps cannot be accomplished without an operable lathe and a qualified operator:

- Wearing ring replacement (both casing and impeller)
- Proper ball bearing fit-up if shaft or bearing housing dimensions are out of specification

* Flexible coupling replacement
* Pump and motor shaft replacement or repairs

The following actions are recommended:

* All the lathes installed on DDG-37 Class ships should be inspected and repaired as necessary at BOH and each follow-on ROH to ensure that they are in good working order and that all attachments and accessories are available.
* Individual ships should take the necessary steps to ensure that the assigned lathe operators are qualified in the operation and maintenance of the equipment.
* DDG-39 should be provided with a lathe capable of accommodating the impeller diameter of the largest installed centrifugal pump. A lathe with a swing greater than 10" is recommended.

3.1.1.2 Technical Documentation

Centrifugal firepump overhauls are currently being accomplished by Ship's Force and IMA personnel using different manuals. At the IMA level the pumps are being overhauled by maintenance personnel using preliminary versions of a Shop Procedures Manual for Centrifugal Pump Repair that was prepared for PMS 306 in support of the Shop Qualification Improvement Program (SQIP). The manual, intended for IMA personnel only, covers all aspects of centrifugal pump repair, including bearing removal and replacement. Ship's Force personnel are using only the manufacturer's technical manual, which is less comprehensive and does not provide the required detailed procedures.

A manual similar to the Shop Procedures Manual has been prepared for the COMNAVSURFLANT Centrifugal Pump Overhaul Training Team. This manual, Centrifugal Pump Repair, Volume I, is currently in review; it covers all aspects of centrifugal pump repair.

A third manual, Bearing Handling and Maintenance for Extended Operating Cycle, is currently being written for NAVSEC 6107. Designed specifically for Site Teams and IMAs, it covers the procedures to be used in the removal and installation of NT-3 (noise-tested) bearings in electric motors on submarines.

Information from all three of these manuals is applicable to centrifugal pump repair at the shipboard level, especially in the areas of inspection, measurement, and repair techniques. A comprehensive centrifugal pump repair manual that combines all of the information in those previously described should be developed and made available at the organizational level to augment the manufacturers' technical manuals. It should include procedures for all aspects of centrifugal pump repair, from the use of the shipboard tag-out procedures to the final quality assurance check when the pump is returned to service. As a minimum, it should address wearing ring installation, ball bearing fit-up criteria, ball bearing

handling and installation (including the use of ball bearing heaters), alignment (both shaft and flange-to-flange alignment), and proper repair techniques (including the use of bench rests, precision measuring instruments, and Quality Control).

It is recommended that Ship's Force personnel be provided with a suitable Centrifugal Pump Repair Manual to improve the organizational-level maintenance effort.

3.1.1.3 Electric Motor Winding Insulation

IMAs are currently rewinding motors in accordance with NAVSEA 0900-LP-060-2010, Technical Manual, Electrical Machinery Repair, Volume I, Electric Motor Repairs. This was developed as a "bench type" manual for implementation by TYCOMs in IMAs. The information and procedures are clearly presented and are easy to follow. A visit to two IMAs revealed that the Shop Qualification Improvement Program (SQIP) has been instrumental in expanding the use of NAVSEA 0900-LP-060-2010. Excerpts from the technical manual are being used routinely in the Rewind Quality Assurance Program. The rewound motors resulting from this procedure have drip-proof windings, but they are not considered adequate to provide enough protection from the high-moisture environment of pump rooms, engine rooms, and fire-rooms. In an effort to improve the existing moisture-proofing of electric motors, NAVSEC is investigating the use of a "sealed insulation system". This new system uses different varnishes and a vacuum-pressure impregnation procedure that shows promise of effectively reducing the number of electric motor rewinds resulting from moisture entering the windings. The detailed procedures for rewind and vacuum-pressure impregnation of an electric motor are now under review by NAVSEC.

Sealed-insulation electric motor rewinds will be accomplished by certified industrial activities within the next calendar year. The certification process will be conducted under the auspices of NAVSEC and will include such tests as operating a rewound motor under water (a requirement for certification only and not a production quality control test due to hydrodynamic force considerations). A major drawback to full implementation of the sealed insulation system is the problem that will be encountered by IMAs in attempting a conventional rewind on a motor equipped with the sealed insulation system. Conversations with NAVSEC and AD-38 Rewind Shop personnel indicate that conventional burn-out-oven procedures for insulation and winding removal cannot be utilized with the sealed insulation system. Special equipment in the form of winding cutters, pullers, and burners will be required if IMAs are to rewind electric motors equipped with a sealed insulation system. NAVSEC and TYCOM technical codes are investigating procedures and special equipments required to provide IMAs with the capability to remove sealed insulation system windings and rewind electric motors using conventional procedures and insulation when a certified industrial facility is not available.

The sealed insulation system, when implemented, promises to be an excellent long-term solution to the high rate of electric motor rewinds for motors subjected to high-moisture environments. It is therefore recommended that a procedure be developed to rewind firepump electric motors utilizing the sealed insulation system.

3.1.1.4 Ball Bearing Installation Procedures

Cognizant technical personnel at the Naval Ship Research and Development Center (NSRDC), Annapolis, Maryland, currently involved in ball bearing failure-rate testing reported that the quality of the ball bearings currently in the Navy Supply System is excellent. It appears, then, that other factors must be responsible for the high failure rate. NSRDC personnel have indicated that the most important factors are:

- Improper ball bearing installation procedures
- Noncompliance with ball bearing fit-up criteria
- Misalignment of the pump/motor shaft

IMAs are installing ball bearings in rewound electric motors in accordance with NAVSEA 0900-LP-060-2010, Technical Manual for Electrical Machinery Repair, Volume I, Chapter 1, Sections 6 and 7. According to technical personnel at NAVSEC and NSRDC, Annapolis, Maryland, the procedures and fit-up criteria used in bearing replacement on electric motors are applicable to most centrifugal pump applications as well.

Discussions with Ship's Force personnel indicated that bearing removal and installation practices varied greatly from ship to ship depending on the experience of the individual performing the maintenance. Neither bearing heaters nor bearing presses are normally available on DDG-37 Class ships. Consequently, bearings are being preheated in galley ovens or with torches. Bearings that are not preheated are normally tamped on with brass stock being used as a buffer.

A section of the recommended Centrifugal Pump Overhaul Manual should be devoted to standardizing specific procedures to be employed by Ship's Force in ball bearing removal, handling, storage, and installation.

It is recommended that the following actions be taken:

- Provide Ship's Force maintenance personnel with suitable ball bearing heaters.
- Ensure that a section of the recommended Centrifugal Pump Overhaul Manual contains a section on ball bearing removal and replacement.

3.1.2 General Centrifugal Pump Maintenance Strategy

Conversations with cognizant shipboard maintenance personnel revealed that many of the normal repair actions on centrifugal pumps can be

accomplished by Ship's Force personnel. Specific repairs that normally cannot be accomplished by these personnel include the following:

- Pump casing repairs
- Pump shaft manufacture
- Pump motor balancing
- Electric motor rewind
- Electric motor shaft manufacture or replacement (a press is required to remove and replace the rotor)
- Steam turbine wheel repairs and balancing

These repairs to the Firemain and Auxiliary Machinery Cooling Water Systems can be accomplished by either depot or IMA maintenance personnel. Full-scale Class "B" overhauls of steam turbines can be performed by IMAs, but depot-level industrial activities are preferred since they are better suited, having better-equipped facilities and more experienced personnel.

It is recommended that all Firemain and Auxiliary Machinery Cooling Water System maintenance, except for overhaul of the firepump turbines, be accomplished at the organizational and IMA levels. Firepump turbine overhaul should be accomplished at a depot-level industrial activity.

3.2 FIREMAIN SYSTEM

The DDG-37 Class Firemain System contains six 500-gallon-per-minute (gpm) single-stage, horizontal centrifugal pumps -- four electric-motor-driven and two steam-turbine-driven. Figure A-1 of Appendix A is a line diagram of the typical DDG-37 Firemain System showing the pumps, their location, and how they are numbered. Table 3-4 identifies the type of driver and location of the firepumps of the Firemain System.

Table 3-4. DDG-37 CLASS FIREPUMP DRIVERS AND LOCATIONS

Pump Number	Driver	Location
1	Motor	No. 1 Pump Room (Forward Pump Room)
2	Turbine	No. 1 Fire Room (Forward Fire Room)
3	Motor	No. 1 Engine Room (Forward Engine Room or Main Control)
4	Turbine	No. 2 Fire Room (After Fire Room)
5	Motor	No. 2 Engine Room (After Engine Room)
6	Motor	No. 2 Pump Room (After Pump Room)

3.2.1 Firepump Improvement Program

A DART Management Program for firepump improvement was implemented in July 1971. The principal problems associated with the firepumps were identified as erosion and corrosion of the cast gun-metal pump casings. As a result of the DART Program, steps were taken to reduce these problems by procuring stainless steel casings and revising the military specification for future procurements of centrifugal pumps. The revised material specifications for salt water firepump manufacture are:

- Casings and impellers of stainless steel
- Casing wearing rings of monel
- Ringless impellers
- Mechanical seals

Appendix C provides a comparison of the original firepump specification and the specification that was modified as a result of the DART Program (MIP-P-1739D).

To date, only 8 of 60 DDG-37 Class firepumps have stainless steel casings installed, and the degree of pump reliability improvement achieved through the DART Program has yet to be determined. These eight pumps are nearly identical to the Warren Type -3 DBH-10 except that the pump casings are made of stainless steel, and they are supported by APL 016021445. Table 3-5 lists the ships having stainless steel firepump casings.

Table 3-5. STAINLESS STEEL FIREPUMP CASINGS (APL 016021445)

Hull Number	Quantity	Pump Number	Date Installed
DDG-38	1	Unknown	March 1975
DDG-39	1	3	June 1976
DDG-40	1	Unknown	September 1975
DDG-42	1	Unknown	June 1975
DDG-44	2	3 and 5	May 1975 and April 1976
DDG-46	2	Unknown	February 1976 and November 1976

Visits to three DDG-37 Class ships, two of which had the new stainless steel pumps installed, revealed that only one of the ships had the correct APL for the new pump. Two ships were reporting maintenance data for the stainless steel pumps under the old APL (016020494) for the cast gun-metal pump casing. No MDS data had been reported against APL 016021445

for the stainless steel pumps as of 20 October 1976. Ship's Force personnel operating the new pumps reported that during the limited period of operation, the pumps seemed to be reliable and required little maintenance.

It is recommended that APL 016021445 be provided to all ships with stainless steel firepumps and that steps be taken to assure that shipboard allowances for spare parts are adequate.

3.2.2 Warren Type -3 DBH-10 Firepump

3.2.2.1 Background

The Warren Type -3 DBH-10 firepump is a horizontal, centrifugal, split-casing volute unit equipped with a double suction impeller, external grease-lubricated ball bearings and internal water-lubricated sleeve bearings. The pump is supported by APL 016020494. It can be driven by either a steam turbine, supported by APL 057950042, or an electric motor, supported by APL 174750564, depending on the particular configuration of the pump. Torque is transferred from driver to pump via a flexible coupling manufactured by the Falk Corporation and supported by APL 782350005.

All firepumps installed on the DDG-37 Class are normally started and stopped manually. This can be accomplished remotely for firepumps 1, 3, 5, and 6 (all electric-motor-driven). Numbers 2 and 4 use 600 psi auxiliary steam as a prime mover, and their operation requires that a main boiler be steaming. Since they are turbine-driven, they must be started and stopped locally. Firepumps 3 and 5 are equipped with an automatic start feature that is actuated by a flow switch in the piping of the Terrier missile booster suppression system. If a fire started in the missile magazine and the automatic booster suppression system went into operation, the firemain pressure would drop significantly because of the increased flow of the firemain to the booster suppression nozzles. The flow switches in the system would sense the flow and automatically start firepumps 3 and 5, which would augment the firemain. If firepumps 1, 2, 4, or 6 had to be started manually, there would be an attendant loss of time to bring the firemain pressure up. The automatic-start capability of firepumps 3 and 5 therefore plays a critical role in the security of the missile magazine and, ultimately, the ship itself.

Conversations with three DDG-37 Class ship Engineer Officers indicated that the steam-turbine-driven firepumps (2 and 4) are normally operated when the ship is either under way or moored and steaming auxiliary. The electric-motor-driven firepumps (1 and 6) located in normally unmanned pump rooms are reserved for emergency in port use only and as a result are operated sparingly. The electric-motor-driven firepumps in the engine rooms (3 and 5) are operated primarily in port or as a back-up when the ship is under way and either the No. 2 or No. 4 turbine-driven firepump is out of commission for repairs of PMS checks. As a result, firepumps 3 and 4 are operated more than the other firepumps.

Normal operating procedure dictates that a minimum of two firepumps be on the line at all times. Some ships report being able to maintain 125 psig on the firemain with only one pump, but this is more the exception than the rule. The Ship's Information Book (SIB) for DDG-37 Class ships [SIB, DLG-9 (DDG-40), NAVSHIPS 0905-475-4010, Volume I] has a table of "sample firepump combinations with missiles aboard" showing various firepump combinations that can be used during various material conditions of readiness. The SIB places no restriction on the underway operation of firepumps 1 or 6. In actual practice, the provisions of the SIB are not being followed, as indicated by the Engineer Officers of all three DDG-37 Class ships visited. They stated that because of their location, they did not operate firepump 1 or 6 while the ship was under way for fear that the pitching of the ship in a seaway could cause a loss of suction to the pumps and thus damage the internal parts.

Further investigation revealed that the sea chest providing sea suction for firepump 1 is located at approximately frame 16 and is near the forefoot of the hull. In a heavy seaway, accompanied by the pitching motion of the bow, it is possible that this pump could lose suction because of (1) emergence of the sea chest or (2) hydrodynamic flow separation in the vicinity of the sea chest. However, this possibility is considered minimal since the No. 1 firepump sea chest is shared with the suction line from the No. 1 Emergency Diesel Generator Salt Water Circulating Pump and the Emergency Diesel has no restriction against operating in heavy weather conditions, if necessary, to provide emergency power.

Similarly, the sea chest providing sea suction for firepump 6 is located at approximately frame 191 and is in the stern cut-away section of the hull. It is shared with the suction line from the No. 2 Emergency Diesel Generator Salt Water Circulating Pump. This Emergency Diesel Generator is also designed to operate without restriction in heavy weather conditions, if necessary, to provide emergency power. The No. 6 firepumps on all DDG-37 Class ships, except DDG-43 and DDG-44, are provided with a wet vacuum pump and priming valve for priming the pump on start-up. This arrangement also affords a measure of protection against loss of suction when the ship backs down since propeller backwash could create turbulence in the area of the sea chest, causing the pump to become airbound. Since there is no recorded evidence that firepumps 1 and 6 have ever lost suction during underway operation and there is no recorded restriction on their underway operation, it is concluded that these firepumps can be operated safely while the ship is under way with little danger of loss of suction. It is therefore recommended that a uniform firepump operating policy be promulgated and that the operating times on the firepumps be changed in such a way as to distribute the maintenance burden evenly. (The following sections identify the differences in maintenance burden experienced by the various pumps and their associated drivers.)

3.2.2.2 Overview of Pump Maintenance Burden

MDS data, as shown in Table 3-1, revealed that the maintenance man-hour burden associated with the firepump accounted for 50 percent of the total man-hour burden reported against the selected Firemain System APLs.

Parts usage information shown in Table 3-2 is indicative of the types of repair parts historically required for maintenance actions during the data period.

CASREP analysis revealed that 18 reports were submitted against the firepump during the period 1 July 1973 to 30 June 1976. This represents 32 percent of the total CASREPs submitted against the entire system and corresponds to an average CASREP submittal rate of 0.86 CASREPs per ship operating year for the firepumps. An average CASREP submittal rate for the Firemain System during the CASREP data period was 2.68 CASREPs per ship operating year (see Appendix B).

Discussions with Ship's Force, IMA, SIMA, and NAVSEC personnel indicated that the firepump was a high-burden item. From these discussions, a typical significant maintenance action for the firepump was defined as repair or replacement of the following:

- Wearing rings
- Bearings
- Rotor assembly
- Shaft
- Impeller
- Casing
- Flexible coupling

The specific maintenance-related problems associated with each of the listed firepump components are addressed in the following sections.

3.2.2.3 Wearing Rings

The Warren, type -3 DBH-10 firepump, supported by APL 016020494, was originally manufactured with a cast gun-metal casing, cast gun-metal impeller wearing rings, a monel impeller, and cast bearing-bronze casing wearing rings, with the casing wearing rings being of a softer metal than the impeller wearing rings (see Appendix C). The original impeller wearing rings (gun metal) were interference-fitted to the monel impeller and held in place with set screws. The direct contact of the two dissimilar metals resulted in a galvanic-corrosion problem. This same problem was found to exist at the interface between the gun-metal pump casing and the bronze casing wearing ring. In the latter case the problem was less severe because of the rubber O-ring seal between the casing wearing ring and the casing. A result of the DART firepump improvement program was to change the wearing ring material as follows:

- Change the impeller wearing rings from gun metal to stainless steel
- Change the casing wearing rings from bronze to monel

An Item Description (Form DD-146) readout was conducted on 11 October 1977 by personnel in the technical section of SPCC Mechanicsburg, Pa., to determine the material composition of the firepump wearing rings currently stocked in the Naval Supply System. This inquiry revealed that the casing wearing ring material is monel, which is in accordance with NAVSEC recommendations, but the impeller wearing ring material currently stocked is stainless steel, Class 303, which is not an acceptable material. Conversations with NAVSEC Code 6153 indicated that the use of Class 303 stainless steel impeller wearing rings on a monel impeller in a firepump is unsuitable for salt water applications and that the galvanic corrosion at the stainless steel-monel interface would be greater than that experienced with the original monel impeller and gun-metal wearing ring.

Table 3-6 shows the composition of the firepump wearing rings currently stocked in the Navy Supply System.

Table 3-6. WEARING RINGS IN SUPPLY SYSTEM

NSN	Description	Material
9C 4320-00-479-8861	Casing Wearing Ring	Nickel-copper alloy (monel), QQ-N-288, Composition B or D
9C 4320-00-541-9064	Casing Wearing Ring (Replaced by NIIN 479-8861 effective 2/73)	Original casing wearing ring made of bronze
9C 4320-00-479-8862	Impeller Wearing Ring	Stainless steel, QQ-S-763, Class 303, Composition A
9C 4320-00-541-9065	Impeller Wearing Ring (Replaced by 479-8862 effective 2/73)	Original impeller wearing ring made of gun metal

The recommended near-term solution is to replace the currently installed Class 303 stainless steel impeller wearing ring with one manufactured from monel, QQ-N-288, Composition B or D. This will entail assigning a new NSN for the monel wearing ring and revising APL 016020494 to reflect the change in material support. These recommendations are compared in Appendix C with currently stocked Navy materials.

3.2.2.4 Bearings

The firepump is equipped with two externally grease-lubricated ball bearings, a thrust bearing consisting of a size 307 double ball bearing and a size 307 single ball bearing. Table 3-2 shows that the thrust bearing was replaced 225 times and the single bearing 219 times during the data period.

Comments of NSRDC personnel reported in Section 3.1.1.4 suggest that the bearings stocked in the Navy Supply System are perfectly adequate for their intended use. However, it was further stated that current bearing installation practices used in the Fleet are varied and are of marginal acceptability, resulting in the high rate of bearing replacement noted. The provision of a comprehensive centrifugal pump overhaul manual for individual ships, as recommended in Section 3.1.1.2 of this report, could reduce the number of bearing replacements.

During analysis of the firepumps, it was further noted that the procedure currently used to grease the ball bearings does not ensure that the old grease in the ball bearing is purged and replaced by new grease. This may have contributed to the high bearing replacement rate by not allowing an adequate flow of new grease. The existing drain plug on the bearing housings is directly below the grease cup or zerk fitting, and it is possible that the fresh grease will flow directly out of the drain hole. The lubrication procedure could be improved by moving the drain hole to the opposite side of the ball bearing, thus forcing new grease to flow through the bearing in such a way as to ensure that fresh grease is introduced to the contact points of the ball bearings and the old grease is flushed out. Figure 3-1 graphically describes the proposed change.

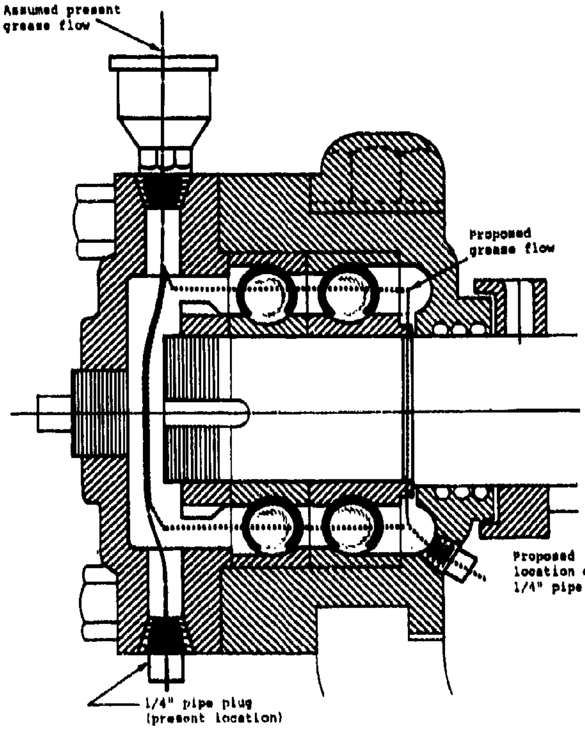


Figure 3-1. TYPICAL FIREPUMP BEARING AND HOUSING

It is recommended that a ShipAlt be developed to implement this recommended firepump bearing housing change on both bearings of the installed firepumps of the DDG-37 Class.

3.2.2.5 Casings

Table 3-7 shows the number of reported significant casing-related maintenance actions per pump. Firepumps 3 and 5 had far more reported casing repairs than the other four firepumps. The MDS narratives indicated that erosion of the pump casings was a serious problem. Section 3.2.2.1 addressed firepump utilization on DDG-37 Class ships, indicating

Table 3-7. CASING REPAIRS

Pump Number	Number of Actions Requiring Casing Repairs*	Percent of Total
1	2	6.5
2	2	6.5
3	13	42.0
4	0	0.0
5	10	32.0
6	4	13.0
Total	31	100.0

*All ships of the DDG-37 Class.

that historically firepumps 3 and 5 were operated more than the other four installed firepumps. The fact that they have experienced more problems with pump erosion tends to confirm that they are used more. Since the pump casings on all six installed firepumps are identical, it is concluded that the higher utilization of pumps 3 and 5 is responsible for their higher rate of pump casing repairs. Operating all firepumps on an

equal operating basis, as recommended in Section 3.2.2.1, will tend to distribute the pump casing erosion problems across all six installed firepumps, but it will not eliminate the problem. One of the principal recommendations of the DART Program, discussed in Section 3.2.1, was the revision of MIL-P-17639 to provide for the use of stainless steel in pump casing manufacture to prevent problems due to casing erosion and corrosion. Therefore, it is recommended that a ShipAlt be developed to install stainless steel casings on all DDG-37 Class ship firepumps as they become available. On the basis of current pump utilization, pumps 3 and 5 should be given priority for stainless steel pump casings. Until this ShipAlt can be implemented, erroded cast gun-metal casings should continue to be repaired as necessary.

Pump casing rebuilding and machining are beyond the capabilities of Ship's Force maintenance personnel. The USS PUGET SOUND (AD-38) has had success in the repair of eroded cast gun-metal casings by using a pre-machined filler piece that is then seal-welded to the machined areas of erosion. RAM Enterprises, a civilian contractor engaged in cast gun-metal pump repairs, builds of the eroded areas directly by welding on new material and then machining it down. Both methods give good results for the short term. Data on long-term performance of pumps whose casings have been repaired by either method is not available. NAVSEC should determine which of the two methods currently being employed provides the best long-term results and establish uniform casing repair procedures. The long-term solution to gun-metal casing erosion is the use of stainless steel pump casings as discussed earlier.

3.2.2.6 Flexible Couplings

The flexible coupling between pump and driver is a grid-type flexible coupling manufactured by Falk Corporation (APL 782350005). The two coupling halves are rough-bored by the manufacturer and require additional machining before installation. Both halves require a tapered inside machine cut for proper fit-up.

The coupling is not considered to be a significant problem since only 36 of 60 were replaced during the data period. Normally one entire coupling is carried on board plus one spare grid. Repair by Ship's Force becomes a problem only if they are unable to machine the taper required for the on-board spare. This potential problem is related to the engine lathe problems discussed in Section 3.1.1.1. The two primary contributing factors in flexible coupling wear are improper lubrication and misalignment. Both of these problems can be reduced by providing a centrifugal pump overhaul manual to Ship's Force, as recommended in Section 3.1.1.2, which would give detailed instructions for proper installation and alignment.

3.2.2.7 Frequency of Repair

In order to determine the mean time between significant firepump maintenance actions, MDS narrative data were examined in detail, and 241 significant maintenance actions (as defined in Section 3.2.2.2) were found to have been accomplished during the data period. Table 3-8 summarizes the identified significant maintenance actions by firepump number, the number of actions accomplished by IMA and Ship's Force maintenance personnel, and the mean time between significant maintenance actions in months. The mean time between significant maintenance actions was calculated by using a Weibull hazard plot*. The data period used for the Weibull analysis extended from the date of the first significant maintenance actions to the end of the

Table 3-8. SIGNIFICANT MAINTENANCE ACTIONS FOR FIREPUMPS (PUMP ENDS)

Maintenance Actions						Mean Time Between Significant Maintenance Actions in Months*
Pump	Driver	IMA	Ship's Force	Total	Percent of Total	
1	Motor	9	21	30	12	22
2	Turbine	11	25	36	15	16
3	Motor	32	32	64	27	9
4	Turbine	11	13	24	10	21
5	Motor	23	36	59	24	11
6	Motor	11	17	28	12	21
Total		97	144	241	100	-
Percent of Total		40	60	-	-	-

*The mean times between significant maintenance actions were calculated by using the censored data as described in Appendix D.

*"Hazard Plotting for Incomplete Failure Data", W. Nelson, *Journal of Quality Technology*, No. 1, pp 27-52, 1969. The Weibull Hazard plot was also used for subsequent calculations of mean time between significant maintenance actions (Tables 3-10, 3-11, 3-13, and 3-15).

MDS data period. The time spent in ROH and RAV was not considered; however, because of the method of determining the starting point for the Weibull analysis, the Weibull analysis period does not equal the ship operating years. Appendix D presents the data used to calculate the means.

Table 3-8 indicates that firepumps 3 and 5 accounted for 27 percent and 24 percent, respectively, or more than 50 percent of the total significant maintenance actions, and had the shortest mean time between significant maintenance actions. With the exception of the drivers, all of the pumps are identical; therefore, the most logical reason for the higher maintenance burden and lower mean time between significant maintenance actions is an operating time difference between the firepumps. Conversations with Ship's Force personnel, as discussed in Section 3.2.2.1, confirm that firepumps 3 and 5 are in fact operated most, followed by pumps 2 and 4, and 1 and 6. The principal problem associated with routinely operating firepumps 3 and 5 rather than the other firepumps is the reduction in the effectiveness of their automatic start capability in the event the booster suppression system is activated. Firemain augmentation in support of the booster suppression system is automatically accomplished if firepumps 3 and 5 are secured and set to start automatically; however, if they are already in operation, firepumps 1 and 6 have to be manually started, with an attendant loss of time to bring the firemain pressure up.

It is therefore recommended that a uniform policy for firepump operation on the DDG-37 Class be established by TYCOM to equalize the maintenance required between the installed firepumps and to assure maximum safety in the event the booster suppression system is activated.

3.2.2.8 Maintenance Strategy

This analysis has shown that the mean time between significant maintenance actions is short. Since redundancy is built into the firemain system (2 of 6 firepumps required for normal system operations) and all firepump repairs are within the capability of either Ship's Force or an IMA, it is concluded that a run-to-failure maintenance strategy should be adopted for the firepumps. There is no penalty for an in-service failure, because (1) the firepumps are redundant and (2) there is no significant difference in the maintenance burden associated with a routine open-and-inspect procedure and that associated with a normal firepump repair resulting from an in-service failure.

It is further recommended that the annual open-and-inspect PMS requirement for both the electric-motor-driven and the turbine-driven firepumps be changed to a situation requirement. The man-hour requirements should also be increased from 8 to 16 hours on the basis of ship visit inquiries. This check would then be accomplished when the firepump was opened for corrective maintenance.

3.2.2.9 Recommendations

The following is a summary of the recommendations applicable to the Warren Type -3 DBH-10 firepump:

- Near Term
  - TYCOM establish a uniform firepump operating policy to:
    - Operate firepumps 2 and 4 whenever steam is available.
    - Operate firepumps 1 and 6 in port or when under way when firepumps 2 and 4 are not available.
    - Keep firepumps 3 and 5 set up for automatic start to the maximum extent possible (if this is accomplished, the priority for stainless steel pump replacement changes since firepumps 3 and 5 will operate less than the other 4 firepumps and thus should not be replaced by stainless steel firepumps before the other 4).
  - Change the material requirements for the impeller wearing rings of the firepumps supported by APL 016020494 from stainless steel, Class 303, to monel, QQ-N-288, Composition B or D.
  - Assign an NSN to the monel impeller wearing ring, and revise APL 016020494 accordingly.
  - NAVSEC determine the best method for gun-metal casing repair and promulgate uniform repair instructions.
  - Use a run-to-failure maintenance strategy for the installed firepumps of the DDG-37 Class as discussed in Section 3.2.2.8.
  - Change the periodicity of MRC C3-C91K of MIP E-28/252 and MRC 55-G81Q-N of MIP E-37/51 from Annual (A) to Situation Requirement (R).
- Long Term
  - Provide a comprehensive centrifugal pump overhaul manual, as discussed in Section 3.1.1.2, to individual ships to standardize bearing removal and installation procedures.
  - Develop a ShipAlt to implement the recommended change in the firepump bearing housing vent drain as described in Figure 3-1.
  - Develop a ShipAlt to install stainless steel casings on all DDG-37 Class firepumps.
  - Ensure that all DDG-37 Class ships are equipped with a fully operational lathe as discussed in Section 3.1.1.1.

3.2.3 Reliance 60 HP Firepump Electric Motor

3.2.3.1 Background

The electric motor for firepumps 1, 3, 5, and 6 on the DDG-37 Class is a 60 hp, 3600 rpm, 3-phase, 440 volt, drip-proof protected motor manufactured by the Reliance Electric and Engineering Company. The motor is supported by APL 174750564.

The recommendation made in Section 3.2.2.1 concerning the historical and proposed operating modes of the installed firepumps is applicable to the firepump electric motors. In particular, the automatic start features of pumps 3 and 5, the remoteness of pumps 1 and 6, and the unequal operating times are especially pertinent to the following discussions.

3.2.3.2 Overview of Motor Maintenance Burden

MDS data, as shown in Table 3-1, revealed that the maintenance man-hour burden associated with the firepump electric motor accounted for 25 percent of the total man-hour burdens reported against the selected Firemain System APLs. Parts usage information shown in Table 3-2 is indicative of the types of repair parts historically required for maintenance actions during the data period.

CASREP analysis revealed that 26 reports were submitted against firepump motors during the period 1 July 1973 to 30 June 1976. This corresponds to an average CASREP submittal rate of 1.24 CASREPs per ship operating year for the firepump motor.

Discussions with Ship's Force, IMA, SIMA, and NAVSEC personnel indicated that the firepump motor was one of the high-maintenance-burden items in the Firemain System. From these discussions, typical significant maintenance actions for the firepump motor were defined as follows:

- Rewinds
- Bearing replacement
- Shaft replacement

The specific maintenance-related problems of the firepump motor components are addressed in the following sections.

3.2.3.3 Rewinds

A review of MDS narratives revealed that 67 firepump motor rewinds were accomplished during the data period. Table 3-9 lists the number of rewinds on each of the installed firepump motors. It shows that firepump motors 1 and 6 have experienced more rewinds than 3 and 5. Comments concerning firepump utilization in Section 3.2.2.1 confirmed that pumps 3 and 5 were operated more than 1 and 6. Therefore, there appears to be a correlation between the relatively low firepump operating time and a high rate

Table 3-9. FIREPUMP ELECTRIC MOTOR REWINDS		
Motor	Rewinds	Percent of Total
1	21	31
3	12	19
5	7	11
6	26	39
Total	67	100

of required firepump motor rewinds for firepumps 1 and 6. No firm data were found to support the theory that higher electric motor use equated to fewer motor repairs, but a logical explanation can be postulated. Since firepump motors 3 and 5 were almost always operating, they remained warm and did not allow condensation and collection of water in the windings. Also, the fact that firepump motors 1 and 6 had more rewinds may be accounted for by their being located in poorly ventilated, remote, unmanned pump rooms, where humidity is high. When these pumps are not run for extended intervals, condensation forms in the windings. This can result in grounds in the windings and may well cause a motor to burn out upon start-up. A near-term solution is to establish a PMS requirement to operate firepumps 1 and 6 daily to warm up and dry out the electric motor windings. Equalization of the use of the firepump motors would increase the use of firepump motors 1 and 6, which should also help to reduce the number of motor rewinds. A long-term solution is the implementation of a procedure for rewinding firepump electric motors using the sealed insulation system (discussed in Section 3.1.1.3), which is less susceptible to grounding from moisture.

3.2.3.4 Bearings

The firepump motors are equipped with two double-shielded ball bearings. Table 3-2 shows that both bearings experienced a high rate of replacement during the data period. There were no firm data to indicate a problem with these bearings other than the problems concerning installation and removal procedures discussed in Section 3.1.1.4. Therefore, it is recommended that Ship's Force personnel be provided with a comprehensive manual that would standardize ball bearing removal and installation procedures. This should reduce the number of bearing replacements required.

3.2.3.5 Shaft Replacement

A shaft must be replaced when it is bent or the area of the bearing journals cannot be dressed up adequately to permit bearing installation in

accordance with the fit-up criteria required for that size bearing. The principal cause of bent shafts and scored journals is the improper use of bearing pullers during bearing removal. A reduction in shaft replacements would be realized by the use of a suitable Centrifugal Pump Overhaul Manual as discussed in Sections 3.1.1.2 and 3.1.1.4.

3.2.3.6 Frequency of Repairs

To determine the mean time between significant firepump motor maintenance actions, MDS narrative data were examined in detail, and 97 significant maintenance actions (as defined in Section 3.2.3.2) were found to have been accomplished during the data period. Table 3-10 summarizes the significant maintenance actions by firepump motor number, the number of actions accomplished by IMA and Ship's Force maintenance personnel, and the mean time between significant maintenance actions.

Table 3-10. SIGNIFICANT MAINTENANCE ACTIONS FOR FIREPUMP MOTORS

Maintenance Actions					Mean Time Between Significant Maintenance Actions in Months*
Motor	IMA	Ship's Force	Total	Percent of Total	
1	27	4	31	32	19
3	13	8	21	22	38
5	7	3	10	10	43
6	27	8	35	36	14
Total	74	23	97	100	-
Percent of Total	76	24	-	-	-

*The mean times between significant maintenance actions were calculated by using the censored data as described in Appendix D.

Table 3-10 indicates that the firepump motors 1 and 6 accounted for 68 percent of the significant maintenance actions and had a mean time between significant maintenance actions considerably lower than that of firepump motors 3 and 5. This difference is due primarily to the higher rewind rate of motors 1 and 6 as discussed in Section 3.2.3.2. For the near term, the number of electric motor rewinds required should be reduced by the implementation of the recommendations made in Section 3.2.3.3 to operate firepumps 1 and 6 daily to warm up and dry out the electric motor windings and the recommendations of Section 3.2.2.1 to establish a uniform firepump operating policy to distribute the operating times evenly.

A long-term solution is provided in the recommendations of Sections 3.1.1.3 and 3.2.3.3 to incorporate firepump motors having a sealed insulation system.

3.2.3.7 Maintenance Strategy

A run-to-failure maintenance strategy is recommended for the firepump motors. This strategy is in line with the recommended strategy for the pump ends as described in Section 3.2.2.8. It is predicated on the fact that motor rewinds are almost impossible to predict since they are usually caused by environmental factors which will not be reduced or eliminated by preventive maintenance on the motor windings until the motor windings have improved insulation.

3.2.3.8 Recommendations

The following is a summary of the recommendations applicable to the Reliance 60 hp Firepump Electric Motor:

- Near Term
  - Establish a PMS requirement to operate firepumps 1 and 6 daily to warm up and dry out the electric motor windings.
  - Equalize the operating times of the electric-driven firepumps as discussed in Section 3.2.4.1 to aid in the prevention of motor rewinds on 1 and 6.
  - Use a run-to-failure maintenance strategy
- Long Term - Implement a procedure to rewind the firepump electric motors using the sealed insulation system on all four electric-motor-driven firepumps but with priority given to firepump motors 1 and 6.

3.2.4 Whiton Type BFSCS Firepump Turbine

3.2.4.1 Background

The Whiton type BFSCS turbine is a single-stage, radial flow, multi-impulse steam turbine supported by APL 057950042. Constant firepump discharge pressure is regulated by a Leslie Pump Pressure Regulator supported by APL 882260195, and turbine maximum speed is limited by a speed-limiting governor that is integral to the turbine unit. The turbine and pump have separate foundations that rest on a common bedplate. They are connected via a flexible coupling.

3.2.4.2 Overview of Turbine Maintenance Burden

MDS data, as shown in Table 3-1, revealed that the maintenance burden associated with the firepump turbine and regulator accounted for 23 percent of the total man-hour burden reported against the selected Firemain System APLs. Parts usage information in Table 3-2 shows the repair parts that have had a significant replacement history during the data period.

CASREP analysis revealed that five reports were submitted against the firepump turbine and regulator during the period 1 July 1973 to 30 June 1976, corresponding to an average CASREP submittal rate of 0.24 CASREPs per ship operating year.

Discussions with Ship's Force, IMA, SIMA, and NAVSEC personnel indicated that the firepump turbine is considered to be a low-maintenance-burden item and is fairly reliable. The major effort by Ship's Force centers on preservation of the turbine and its associated piping and repairs to the pressure regulator. From these discussions, a typical significant maintenance action for the firepump turbine was defined as repairs to or replacement of the following:

- Pressure regulator
- Bearings
- Carbon seals

The specific maintenance-related problems associated with each of the turbine components are addressed in the following sections.

3.2.4.3 Pressure Regulator

All DDG-37 Class firepump turbines are equipped with a constant-pressure regulator that monitors firepump discharge pressure and regulates auxiliary steam to the firepump turbine in such a manner as to maintain firemain pressure at the designated set point.

Conversations with cognizant technical personnel revealed that the majority of the repairs to the regulator dealt with replacement of internal parts such as diaphragms, gaskets, power piston rings, and needle valves. This type of part replacement can be accomplished by Ship's Force personnel with the regulator in place in about 6 to 8 man-hours. This estimate is based on discussions with Ship's Force technicians involved in maintenance of the regulator.

As shown in Table 3-1, two different pressure regulators are installed in the DDG-37 Class. The major difference between the two regulators is shown as follows:

APL	Class	Difference
882260195	PTLNS-4	Uses copper-asbestos gaskets
882260469	PTLNS-5	Uses spiral wound gaskets

Other minor differences not related to the maintainability of the regulators include:

APL	Body Material	Remarks
882260195	CMO Steel	Original design
882260469	Steel	Revised design

Manufacturer representatives reported that the PTLNS-5 (supported by APL 882260469) is the newer version of the basic regulator. Both regulators should provide reliable service during an extended operating cycle if they are overhauled in accordance with TRS 0521-086-601. Cognizant repair personnel and manufacturer representatives indicated that overhauls accomplished by facilities other than the manufacturer have not been as successful as overhauls accomplished by the Leslie Company. In the past year the Leslie Company has entered into contracts with several Naval Shipyards (PHNSY, CNSY, NNSY) to provide services for overhaul of regulators and reducing valves, but a satisfactory overhaul of the regulator by an IMA or depot should be possible if the overhaul is performed in accordance with TRS 0521-086-601.

It is recommended that all pressure regulators be overhauled during BOH in accordance with TRS 0521-086-601. It is also recommended that the pressure regulator be overhauled again at each follow-on ROH. No other maintenance except for routine repairs by Ship's Force (diaphragm, piston rings, etc.) should be required during the intracycle.

3.2.4.4 Turbine Bearings and Seals

The firepump turbines on the DDG-37 Class ships are equipped with two gun-metal babbitt-lined, split-half shaft bearings that support the turbine rotor. MDS parts usage indicated that 133 percent of the class population of shaft bearings were replaced during the data period.

A typical bearing failure results from loss of lube oil pressure to the bearings, causing them to wipe. During replacement of the shaft bearings, the carbon packing was also usually replaced. The loss of lube oil was normally attributed to water in the lube oil or to a failure of the swing check valve on the discharge side of the firepump.

Ship's Force personnel reported that one of the major causes of water in the lube oil was condensation in the lube oil sump during periods of nonoperation. The adverse effects of water in the firepump turbine lube oil are minimized by strict adherence to the lighting-off and securing procedures set forth in the Engineering Operating Sequencing System (EOSS). These procedures provide for draining off any water accumulated in the lube oil sump prior to light-off.

A failure of the swing check valve causes the firepump to be driven in reverse by firemain pressure, thus reversing the direction of the firepump turbine rotor. The attached lube oil pump does not pump oil to the journal bearings when it is running backwards; as a result, the turbine journal bearings wipe because of oil starvation.

3.2.4.5 Swing Check Valve

Ship's Force personnel suggested that the 4.0" IPS swing check valves installed on the discharge side of the electric-driven and turbine-driven firepumps contributed greatly to the maintenance burden of the firepumps since a failure of the swing check valve usually resulted in serious damage

to the firepump motor or turbine. One ship of the class reported that the failure of the swing check valve caused the firemain pressure to rotate an electric firepump motor backwards. The reverse rotation of the motor and pump shafts caused the pump sleeves to unscrew and jam the impeller and pump shaft in the firepump casing. The firepump shaft had to be cut to facilitate removal. The failure of the swing check valve on the turbine-driven firepump is even more catastrophic in that the turbine shaft is driven backwards. The installed lube oil pump does not supply oil to the bearings when operating in reverse, and the resultant oil starvation at the wearing surfaces of the turbine journal bearings causes the bearings to wipe.

According to cognizant technical personnel, the swing check valves sometimes "hang up" in the open position and fail to close as designed. The reason for hanging open is usually a failure of the nut that fastens the disc stud to the arm, which in turn is attached via a hinge arrangement to the body of the valve. The failure of this nut causes the disc to become cocked and not seat properly when the firepump is secured and the firemain pressure forces the swing check (disc) to the closed position. The disc, body, arm, and hinge of the valve are made of bronze, while the disc stud and nut are brass. The nut appears to suffer from severe erosion and some galvanic corrosion, which causes the disc to detach from the arm and jam in the body. The nut can be replaced in approximately three to five man-hours without removing the swing check valve from the system.

A near-term solution to the problem is to establish a PMS requirement to inspect the condition of the hinge, stud, nut, and disc of the swing check valve on a monthly basis. This would provide early detection of any corrosion of the internal parts of the valve and reduce the frequency of failures of the swing check valve and the resulting failure of the firepump turbine.

MDS data showed that APL 882035712 was reported by five of ten DDG-37 Class ships as the APL that supported the installed firepump discharge swing check valves. The remaining five ships of the class reported MDS data for firepump swing check valves under several other APLs. A review of TYCOM COSALs revealed that none of the APLs reported in the MDS data are listed as being installed in DDG-37 Class ships. Since this discrepancy exists, it is recommended that a COSAL validation be conducted to ensure that the installed firepump swing check valves are supported by the proper APLs.

3.2.4.6 Frequency of Repair

To determine the mean time between significant firepump turbine maintenance actions, MDS narrative data were examined in detail, and 34 significant maintenance actions (as defined in Section 3.2.4.2) were found to have been accomplished during the data period. Table 3-11 summarizes the identified significant maintenance actions by firepump turbine number, the number of actions accomplished by IMA and Ship's Force maintenance personnel, and the mean time between significant maintenance actions.

Table 3-11. SIGNIFICANT MAINTENANCE ACTIONS FOR FIREPUMP TURBINES

Maintenance Actions					Mean Time Between Significant Maintenance Actions in Months*
Turbine	IMA	Ship's Force	Total	Percent of Total	
2	7	11	18	53	25
4	4	12	16	47	32
Total	11	23	34	100	-
Percent of Total	32	68	-	-	-

*The mean times between significant maintenance actions were calculated by using the censored data as described in Appendix D.

Two firepump turbine overhauls were reported for the data period. MDS parts usage indicated that turbine journal bearings and carbon seals were replaced in both instances. One overhaul was accomplished by an IMA and one by Ship's Force. Both overhauls were within 20 months of the end of the data period, and no significant maintenance was accomplished after the overhauls.

As shown in Table 3-11, the mean time between significant maintenance actions was 25 and 32 months for firepumps 2 and 4, respectively. As previously stated, the reported maintenance actions tended to center on repairs to the pressure regulator and replacement of turbine bearings and carbon seals.

3.2.4.7 Maintenance Strategy

The firepump turbine (including pressure regulator) is the only equipment in the Firemain System recommended for Class "B" overhaul in accordance with TRS 0521-086-601 during BOH and each follow-on ROH. In theory, a turbine overhaul could be accomplished by an IMA; but, as discussed in Section 3.1.2, overhaul by an industrial activity, with its special facilities and more experienced personnel, is preferred. In addition, the removal of the entire turbine assembly, including bedplate, to an industrial repair shop would allow a complete and thorough inspection of the turbine and would facilitate Ship's Force preservation of the firepump turbine foundation and surrounding area.

Historical data indicate that the turbine, with the exception of the pressure regulator, will normally operate satisfactorily during the period from BOH to follow-on ROH with only minor corrective maintenance if the

existing PMS requirements are accomplished. The cycle PMS check, which requires opening the firepump turbine for inspection, will be accomplished by the depot level during BOH and at each follow-on ROH as part of the overhaul. (PMS check C-2, MRC 55-G81S-N of MIP E-37/51-65, is normally scheduled for accomplishment during shipyard overhaul, as per scheduling aid on MIP E-37/51-65.)

A run-to-failure maintenance strategy is recommended during the operating cycle for the firepump turbine.

3.2.4.8 Recommendations

The following is a summary of the recommendations applicable to the Whiton Type BFSCS firepump turbine:

- Near Term
  - Ship's Force personnel continue to accomplish only routine minor repairs to the pressure regulator, such as the replacement of internal parts and gaskets. Neither Ship's Force nor IMA maintenance personnel should attempt to machine or rebuild internal surfaces of the pressure regulator unless they are provided with the exact original dimensions.
  - Develop a monthly PMS requirement to open and inspect firepump swing check valves on firepumps 2 and 4 to check the condition of the hinge, stud, nut, and disc.
  - Adopt a run-to-failure maintenance strategy for the Whiton Type BFSCS firepump turbine.
- Long Term
  - Conduct COSAL validation to ensure that the installed firepump swing check valves are supported by the proper APLs.
  - Depot level accomplish Class "B" overhaul of turbines at BOH and each follow-on ROH in accordance with TRS 0521-086-601.

3.3 AUXILIARY MACHINERY COOLING WATER SYSTEM

The Auxiliary Machinery Cooling Water System contains two 500 gpm, single-stage, horizontal, centrifugal, close-coupled, motor-driven volute pumps that supply sea water to the auxiliary machinery cooling water mains at 50 psig. Appendix A includes a line diagram of the typical DDG-37 Auxiliary Machinery Cooling Water System showing the pumps, their location, how they are numbered, and how the Auxiliary Machinery Cooling Water System interfaces with the firemain via an emergency supply reducer from the firemain to the Auxiliary Machinery Cooling Water System. Table 3-12 presents selected pump information for this system.

Table 3-12. AUXILIARY MACHINERY COOLING WATER PUMPS AND LOCATIONS		
Pump Number	Pump Location	Spaces Serviced
1	No. 1 Fireroom	Forward System: No. 1 Fireroom and No. 1 Engineroom.
2	No. 2 Fireroom	After System: No. 2 Fireroom, No. 2 Engineroom, and the main shaft stern tube cooling, flushing, and sealing.

The Auxiliary Machinery Cooling Water System is split into two independent systems, one serving the forward fireroom and engineroom and the other serving the after fireroom and engineroom. They cannot be cross-connected, and each system is served by a dedicated auxiliary machinery cooling water pump located in its associated fireroom. Suction for each pump is taken from a separate sea chest; discharge is to the auxiliary machinery cooling water main, which distributes the cooling water through branches to the individual auxiliaries served by the system. An emergency cooling water supply is provided for each system via a 125 to 50 psig reducing valve, in each engineroom, from the firemain. This source provides cooling water to the auxiliary machinery when the dedicated pump is down for maintenance.

No CASREPs were reported against the Auxiliary Machinery Cooling Water System equipments during the period 1 July 1973 through 30 June 1976.

3.3.1 Aurora Type GNC Centrifugal Pump

3.3.1.1 Background

The Aurora Type GNC Centrifugal Pump is a 500 gpm, single-stage, horizontal, centrifugal, close coupled motor-driven unit supported by APL 016110076.

3.3.1.2 Overview of Pump Maintenance Burden

MDS data, as shown in Table 3-1, revealed that the maintenance man-hour burden associated with the auxiliary machinery cooling water pump was approximately 27 man-hours per component operating year.

From discussions with Ship's Force, IMA, SIMA, and NAVSEC personnel, a typical significant maintenance action for the auxiliary machinery cooling water pump was defined as repairs to or replacement of the following wearing parts:

- Wearing rings
- Shaft sleeves
- Impeller

The specific maintenance-related problems associated with these components are addressed in the following section.

3.3.1.3 Internal Parts

The wearing rings, both impeller and casing, were replaced at a higher rate in this pump than in the firepumps (see Table 3-2).

On the basis of conversations with Ship's Force personnel, it is speculated that torsional forces exerted on the pump by improperly aligned pump suction and discharge piping have contributed significantly to the maintenance burden of the pump. These forces have caused binding of the impeller wearing rings against the casing wearing rings, resulting in excessive wear. Ship's Force personnel said that loud noises emanating from the pump usually indicated motor bearing failure and dictated securing the pump and opening it to allow access. While the pump is open, the wearing ring clearances are normally checked in accordance with the MRC for the annual open-and-inspect PMS check. Maintenance personnel reported that the clearances were almost always out of tolerance and that wearing rings were replaced as a matter of routine.

The shaft sleeve and impeller are also normally inspected, but are not replaced as often (see Table 3-2). It is therefore concluded that a significant reduction in internal wearing part replacement could be realized by ensuring that the suction and discharge piping alignment (flange to flange) to the pump is such that torsional stresses are not exerted on the pump when the suction and discharge piping is bolted up. This alignment check should be made each time the pump is opened for corrective maintenance. Proper piping alignment should reduce the motor bearing replacement rate as well as the pump internal wearing part replacement rate. Alignment checks are not addressed in detail in either the MRC or the manufacturer's technical manual, but they should be included in the centrifugal pump overhaul manual recommended for development in Section 3.1.1.2.

NSN 9C 4320-00-541-8843, impeller wearing ring, was reported in the MDS data, but this particular NSN is not listed on APL 016110076, which is the APL for the pump. The APL should be changed to reflect the addition of this NSN to it.

3.3.1.4 Frequency of Repairs

To determine the mean time between significant auxiliary machinery cooling water pump maintenance actions, MDS narrative data were examined in detail, and 63 significant maintenance actions (as defined in Section 3.3.1.2) were found to have been accomplished during the data period. Table 3-13 summarizes the identified significant maintenance actions by auxiliary machinery cooling water pump number, the number of actions accomplished by IMA and Ship's Force maintenance personnel, and the mean time between significant maintenance actions.

Table 3-13 shows that the maintenance burden is rather evenly distributed between the two pumps and that the mean times between significant maintenance actions are identical, suggesting that the pumps are probably

Table 3-13. SIGNIFICANT MAINTENANCE ACTIONS FOR AUXILIARY MACHINERY COOLING WATER PUMPS					
Maintenance Actions					Mean Time Between Significant Maintenance Actions in Months*
Pump	IMA	Ship's Force	Total	Percent of Total	
1	12	18	30	48	17
2	12	21	33	52	17
Total	24	39	63	-	-
Percent of Total	38	62	-	-	-

*The mean times between significant maintenance actions were calculated by using the censored data as described in Appendix D.

operated about the same amount of time and that the different locations (see Table 3-12) do not result in a different maintenance experience. The most important maintenance-related problem that is contributing to the 17-month mean time between significant maintenance actions is the alignment problem discussed in Section 3.3.1.3.

3.3.1.5 Maintenance Strategy

This analysis has shown that the mean time between significant maintenance actions is short. It has further been determined that the primary cause of the short mean time between significant maintenance actions may not be related to the pump itself but to the external forces on it caused by misaligned suction and discharge piping. As shown in Figure A-1 of Appendix A, redundancy is provided by a 125 to 50 psig reducing valve from the firemain in the event of pump failure. Since pump repairs are normally within the capability of Ship's Force personnel, there is no penalty associated with an in-service failure of the pump. It is therefore concluded that a run-to-failure maintenance strategy should be adopted for the auxiliary machinery cooling water pumps and that the annual open-and-inspect PMS requirement be changed to a situation requirement. Further, on the basis of ship visit inquiries, the man-hour requirement should be increased from 5 to 20.

3.3.1.6 Recommendations

The following is a summary of the near-term recommendations applicable to the Aurora Type GNC auxiliary machinery cooling water pump:

- Ship's Force maintenance personnel check the flange-to-flange alignment of the pump and the suction and discharge piping each time the

pump is opened for corrective maintenance, and adjust the pump motor foundation bolts and the piping hangers to correct any misalignment. Detailed technical guidance on how to conduct alignment checks should be provided in a comprehensive centrifugal pump overhaul manual, as discussed in Section 3.1.1.2.

- Adopt a run-to-failure maintenance strategy for the auxiliary machinery cooling water pumps.
- Change the periodicity of MRC 21-A13-CA of MIP A-19/150 from Annual (A) to Situation Requirement (R).
- Add NSN 9C 4320-00-541-8843, impeller wearing ring, to APL 016110076, with an allowance for two on-board spares.

3.3.2 Reliance, 25 HP Auxiliary Machinery Cooling Water Pump Electric Motor

3.3.2.1 Background

The electric motor for auxiliary machinery cooling water pumps 1 and 2 on the DDG-37 Class is a 25 hp, 3600 rpm, 3-phase, 440 volt drip-proof-protected motor manufactured by the Reliance Electric and Engineering Company. It is supported by APL 174750217.

3.3.2.2 Overview of Motor Maintenance Burden

MDS data (Table 3-1) revealed that the maintenance man-hour burden for the auxiliary machinery cooling water pump electric motor was approximately 33 man-hours per component operating year. Parts usage information shown in Table 3-2 is indicative of the types of repair parts historically required for maintenance actions during the data period. No CASREPs were reported against the electric motor during the period 1 July 1973 to 30 June 1976.

From discussions with Ship's Force, IMA, SIMA, and NAVSEC personnel, typical significant maintenance actions for the auxiliary machinery cooling water pump electric motor were defined as follows:

- Rewinds
- Bearing replacement
- Shaft replacement

The specific maintenance-related problems of the auxiliary machinery cooling water pump electric motor are addressed in the following sections.

3.3.2.3 Rewinds

A review of MDS narratives revealed that a total of 67 auxiliary machinery cooling water pump electric motor rewinds were accomplished during the data period. Table 3-14 lists the number of rewinds on each of the motors and shows that the two motors were rewound about the same number of times. In Section 3.3.1.4, it was reported that the auxiliary machinery

Table 3-14. AUXILIARY MACHINERY COOLING WATER PUMP ELECTRIC MOTOR REWINDS		
Motor Number	Rewinds	Percent of Total
1	12	46
2	14	54
Total	26	100

cooling water pumps are operated about equally and that their locations, although in different firerooms, do not significantly affect their maintenance burdens. A review of the MDS narratives and conversations with Ship's Force personnel identified the following as the primary causes of rewinds for these motors:

- Accidental wetting of the motor during washdowns of the space or during maintenance on other equipment (e.g., backflushing lube oil coolers above the motor and allowing salt water to fall on the motor)
- Failure of the packing glands, allowing water to spray on the motor

The problem of accidental wetting is more acute for the auxiliary machinery cooling water pump motors than for most of the other electric motors located on the lower level of the firerooms because they are horizontal instead of vertical motors. The main feed booster pump motor, for example, is vertical and has a shield built into its top that protects it from accidental wetting. The auxiliary machinery cooling water pump motor is horizontal and does not have a shield. Therefore, water can flow over the motor and enter through the air intake on one end, thus grounding out the motor. Some ships have constructed light sheetmetal shields over these motors to protect them from accidental wetting. A near-term, relatively inexpensive recommendation is to have IMAs construct a suitable shield over the motors to protect them from accidental wetting.

Ship's Force personnel reported that packing gland failures on the pump usually caused sea water to be sprayed on the motor, which sometimes resulted in grounding of the windings. The installed packing material is normally Teflon-impregnated braided asbestos with a conventional gland arrangement. A properly installed mechanical seal would probably reduce the number of motor rewinds by reducing the number of times the motors are sprayed with sea water. It is therefore recommended that a ShipAlt be developed to provide the auxiliary machinery cooling water pumps with mechanical seals.

A long-term solution to the high motor rewind rate for auxiliary machinery cooling water pumps is to incorporate an improved method of insulating electric motor windings. The sealed insulation system discussed

in Section 3.1.1.3 promises to be an excellent long-term solution to the high rewind rate for motors subjected to high-moisture environments. It is therefore recommended that these electric motors be rewound with a sealed insulation system.

3.3.2.4 Bearings

The auxiliary machinery cooling water pump motors are fitted with two double-shielded ball bearings. As indicated in Table 3-2, more than 500 percent of the total class population of the installed bearings were replaced during the data period. As discussed in Section 3.3.1.3, the torsional forces exerted on the pump by the misaligned suction and discharge piping are probably the major cause of the high ball bearing failure rate. The recommendations made in Section 3.3.1.3 for ensuring the flange-to-flange alignment of the piping to the pump are applicable to the motor bearings also.

From discussions with Ship's Force personnel, it appears that the maintenance problems associated with ball bearing removal and replacement are similar to those discussed in Section 3.1.1.4 and that the recommendations to provide improved technical documentation and bearing heaters are also applicable to the auxiliary machinery cooling water pump motor.

3.3.2.5 Shaft Replacement

Ship's Force and IMA maintenance personnel reported that shaft replacement is usually caused by the improper use of gear pullers in removing either the motor bearings or the pump impeller. The pump end of the shaft is sometimes damaged by the improper use of a gear puller in that the threaded end becomes flared to such an extent that the impeller nut cannot be installed properly. In many cases, Ship's Force personnel "stub" the shaft and reassemble the pump and motor. The stubbed shaft is normally not balanced since Ship's Force does not have a shaft-balancing capability. This problem is related to the maintenance technique for using bearing pullers and will probably be reduced but never eliminated by the use of the comprehensive centrifugal pump overhaul manual recommended for development in Section 3.1.1.2.

3.3.2.6 Frequency of Repairs

To determine the mean time between significant maintenance actions, MDS narrative data were examined in detail, and 122 significant maintenance actions were identified. Table 3-15 summarizes the identified significant maintenance actions by pump motor number, the number of actions accomplished by IMA and Ship's Force maintenance personnel, and the mean time between significant maintenance actions.

The mean time between significant maintenance actions for the pump and motor are very close (approximately 17 and 13 months, respectively). Since the pump is close-coupled to the motor and the radial support of the pump impeller is provided by the motor bearings, it is theorized that the low

Table 3-15. SIGNIFICANT MAINTENANCE ACTIONS FOR AUXILIARY MACHINERY COOLING WATER PUMP MOTORS

Maintenance Actions					Mean Time Between Significant Maintenance Actions in Months*
Motor Number	IMA	Ship's Force	Total	Percent of Total	
1	28	26	54	44	13
2	35	33	68	56	12
Total	63	59	122	100	-
Percent of Total	52	48	-	-	-

*The mean times between significant maintenance actions were calculated by using the censored data as described in Appendix D.

mean time between significant maintenance actions is driven by the failure of the pump-side motor bearing. This failure is caused primarily by misalignment of the suction and discharge piping to the pump end, which causes torsional forces to be applied to the pump end, wearing rings, shaft, and, ultimately, the motor bearings when the pump suction and discharge piping is bolted up. This problem, as discussed in Section 3.3.1.3, should be reduced by the promulgation and use of the comprehensive centrifugal pump overhaul manual recommended for development in Section 3.1.1.2. The low mean time between significant maintenance actions is also a function of the number of rewinds as discussed in Section 3.3.2.3. This time should be increased by implementation of the recommendations made in Sections 3.3.1.2 and 3.2.2.3 to correct the alignment problem, to develop a comprehensive centrifugal pump overhaul manual, to increase the protection afforded the motor from accidental wetting, and to incorporate a sealed insulation system.

3.3.2.7 Maintenance Strategy

A run-to-failure maintenance strategy is recommended for the auxiliary machinery cooling water pump motors. This strategy is in conformance with the recommended strategy for the pump end as discussed in Section 3.3.1.5.

3.3.2.8 Recommendations

The following is a summary of the recommendations applicable to the Reliance 25 hp Auxiliary Machinery Cooling Water Pump Motor:

- Near Term
  - Install a shield of light sheetmetal over the motor to reduce the number of rewinds due to accidental wetting.
  - Adopt a run-to-failure maintenance strategy for the auxiliary machinery cooling water pump motors.

* Long Term
  * Develop a ShipAlt to provide a mechanical seal for the pump.
  * Rewind the motor, incorporating a sealed insulation system.

3.4 RECOMMENDED MAINTENANCE STRATEGY FOR FIREMAIN SYSTEM COMPONENTS AND AUXILIARY MACHINERY COOLING WATER SYSTEM COMPONENTS

The results of this analysis have shown that the mean time between significant maintenance actions is short for the firepump, firepump motor, firepump turbine, and auxiliary machinery cooling water pump and motor. It has also been shown that there is enough redundancy in the Firemain and Auxiliary Machinery Cooling Water Systems that an in-service failure of one equipment will not normally cause a failure to the system. Since Ship's Force personnel are normally capable of performing corrective maintenance on these equipments, it is concluded that a run-to-failure maintenance strategy should be adopted during the operating cycle for the following equipments of the Firemain and Auxiliary Machinery Cooling Water Systems:

* Turbine and Electric Driven Gun Metal Casing Firepumps
* Firepump Electric Motor
* Firepump Turbine
* Auxiliary Machinery Cooling Water Pump
* Auxiliary Machinery Cooling Water Pump Motor

3.5 BASELINE OVERHAUL REQUIREMENTS

The Baseline Overhaul concept of the DDEOC Program is to provide the maintenance necessary to restore a system to a condition in which, with a well engineered and executed maintenance program, it can be expected to perform satisfactorily over an extended operating cycle. In keeping with this policy, specific Baseline Overhaul requirements for the Firemain and Auxiliary Machinery Cooling Water Systems are as follows:

* Engine Lathes - The Ship's Force maintenance effort is hindered by inadequately maintained engine lathes. It is recommended that all lathes installed on DDG-37 Class ships be inspected and repaired as necessary during BOH to ensure that they are in good working order and that all attachments and accessories are available. It is further recommended that DDG-39 be provided with a lathe capable of accommodating the impeller diameter of the largest installed centrifugal pump, or a lathe with a swing of a minimum of 10".
* Firepump Turbine - A depot-level Class "B" overhaul should be performed in accordance with TRS 0521-086-601 (the pressure regulator is included in the TRS). This recommendation is based on the fact that only a depot-level industrial facility can adequately undertake the removal, repair, balancing, and reinstallation of a steam

turbine with consistent success. The overhaul itself is recommended on the basis of engineering judgment of what would be required to guarantee reliable operation throughout the operating cycle.

The results of this analysis do not support the routine Class "B" overhaul of all of the equipments of the Firemain and Auxiliary Machinery Cooling Water Systems as recommended in the "Repair Profile for Baseline Overhaul (BOH) of DDG-37 Class" of May 1977. Only the recommendation for Class "B" overhaul of the firepump turbine is supported (see Section 3.2.4.7 of this ROE).

Table 3-15 lists the BOH repair recommendations for SWBS 521 and 524 as listed in the DDG-37 Class BOH Repair Profile and the rationale for their deletion.

3.6 INTRACYCLE AND FOLLOW-ON ROH REQUIREMENTS

Ship's Force personnel have the capability to perform major maintenance on the firepump, firepump motor, firepump turbine, auxiliary machinery cooling water pump, auxiliary machinery cooling water pump motor, and valves, with the exception of motor rewinds, motor balancing, and casing repairs. The maintenance actions that cannot be accomplished by Ship's Force (see Section 3.1.2) do not lend themselves to preventive maintenance and are thus normally accomplished only as corrective maintenance. Therefore, the only intracycle maintenance requirements should be the existing PMS actions as modified by recommendations of this report and the Ship's Force performance of all corrective maintenance on system pumps and motors supported by an IMA as necessary.

The only follow-on ROH overhauls recommended are the Class "B" overhauls, in accordance with the TRS 0521-036-601, of the firepump turbine by an industrial facility.

The installed engine lathes should be inspected and repaired as necessary at each follow-on ROH to ensure that they are in good working order and are provided with all the necessary attachments.

Table 3-15. RECOMMENDED CHANGES TO THE DDG-37 CLASS REPAIR PROFILE FOR BOH		
SWBS	**Repair Profile Item**	**Rationale for Deletion**
521	Firemain and Flushing System	
	1. Fire and Flushing Pumps	
	a. Pumps	
	(1) Overhaul IAW TRS	A run-to-failure maintenance strategy combined with an aggressive corrective and preventive maintenance program will preclude the routine overhaul of firepumps at BOH. There was no conclusive evidence that the overhaul of the firepumps at BOH, without regard to material condition, would be desirable or cost-effective. Therefore, routine overhaul of firepumps at BOH is not recommended.
	b. Motors	
	(1) Overhaul IAW TRS	A run-to-failure maintenance strategy is recommended for firepump motors in Section 3.2.3.7 of this ROE. This recommendation is predicated on the fact that motor rewinds and motor bearing replacements are almost impossible to predict since they are usually caused by external factors, including misalignment, which will not be reduced or eliminated by preventive maintenance in the form of routine overhauls of functioning electric motors. Therefore, the routine overhaul of firepump electric motors at BOH is not recommended.
	c. Turbines	
	(1) Overhaul IAW TRS	No change.
	d. Controllers	
	(1) Class "B" Overhaul	Current PMS procedures are adequate to maintain these equipments in good material condition. No significant recurring intra-cycle maintenance has been reported, and there are no data to support the routine overhaul of motor controllers.
	e. Test IAW 1200 psi Procedures	No change.
524	Auxiliary Sea Water System	
	1. Auxiliary Machinery Cooling Water Pumps and Motors	
	a. Overhaul IAW TRS	As discussed in Sections 3.3.1.4 and 3.3.2.6 of this ROE, the mean times between significant maintenance actions for the auxiliary machinery cooling water pumps and motors are 17 months and 13 months, respectively, and a run-to-failure maintenance strategy is recommended by this ROE. There are no data to support the supposition that the routine overhaul of the pump and motor would be cost-effective and would increase the short interval between significant maintenance actions.
	2. Controllers	
	a. Class "B" Overhaul	Current PMS procedures are adequate to maintain these equipments in good material condition. No significant maintenance has been reported, and there are no data to support the routine overhaul of motor controllers.
	3. Test in accordance with 1200 psi Test Procedure	No change.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

This Review of Experience led to the following conclusions:

- The Ship's Force maintenance effort is hindered by inadequately maintained engine lathes (Section 3.1.1.1).
- A comprehensive Centrifugal Pump Overhaul Manual for Ship's Force use is not available (Sections 3.1.1.2 and 3.1.1.4).
- The currently installed drip-proof windings on firepump electric motors and auxiliary machinery cooling water pump electric motors are inadequate (Sections 3.1.1.3, 3.2.3.3, and 3.3.2.3).
- Ball bearing removal and installation practices vary greatly from ship to ship depending on the experience of the individual performing the maintenance (Section 3.1.1.4).
- Ball bearing heaters are not normally available at the organizational level (Section 3.1.1.4).
- Most repair to the equipments of the Firemain and Auxiliary Machinery Cooling Water Systems can be accomplished by Ship's Force personnel with occasional IMA assistance. Only firepump turbine overhauls require a depot-level activity (Section 3.1.2).
- The DART Firepump Improvement Program has resulted in a revision of the military specification for future procurement of centrifugal firepumps and the procurement and installation of eight stainless steel firepump casings in DDG-37 Class ships (Section 3.2.1 and Appendix C).
- Preliminary indications are that the installed stainless steel pumps are demonstrating improved reliability over the cast gun-metal firepumps (Section 3.2.1).
- Firepump (pumps and motors) utilization and firepump location are relevant to the maintenance burden associated with the firepumps (Sections 3.2.2.1 and 3.2.3.3).
- The currently stocked firepump impeller wearing ring is unsuitable for salt water applications (Section 3.2.2.3 and Appendix C).

- The grease flow through the firepump bearing housings could be improved by relocating the bottom vent drain (Section 3.2.2.4).
- Two methods of cast gun-metal firepump casing repairs are currently being used but no preferred method has been identified (Section 3.2.2.5).
- The safety factor afforded by the automatic start feature of firepumps 3 and 5 is not being fully realized because of the lack of a uniform firepump operating policy (Section 3.2.2.7).
- The mean time between significant maintenance actions for firepumps is low (e.g., it varies from 9 to 22 months) (Section 3.2.2.7).
- A run-to-failure maintenance strategy and a change in the periodicity of the annual PMS open-and-inspect requirement for the firepumps is suggested (Section 3.2.2.8).
- The failure of the swing check valve on the discharge side of the firepumps usually results in serious damage to the firepump turbine (Sections 3.2.4.4 and 3.2.4.5).
- A depot-level Class "B" overhaul of the firepump turbines at BOH and follow-on ROH should significantly reduce major corrective maintenance during the operating cycle (Section 3.2.4.8).
- The internal wearing parts of the auxiliary machinery cooling water pumps are replaced at a higher rate than the internal wearing parts of the firepumps (Section 3.3.1.2).
- The mean time between significant maintenance actions for the auxiliary machinery cooling water pumps is low (17 months) (Section 3.3.1.4) primarily because of the flange-to-flange misalignment of the suction and discharge piping to the pump (Section 3.3.1.2).
- Add NSN 9C 4320-00-541-8843, impeller wearing ring, to APL 01611076, with an allowance for two on-board spares.
- A run-to-failure maintenance strategy and a change in the periodicity of the annual PMS open-and-inspect requirement for the auxiliary machinery cooling water pumps is suggested (Section 3.3.1.5).
- The auxiliary machinery cooling water pump electric motors require increased motor winding insulation to reduce the number of rewinds (Section 3.3.2.3).
- With only minor changes, the PMS requirements for the Firemain and Auxiliary Machinery Cooling Water Systems are adequate.

4.2 RECOMMENDATIONS

Corrective actions and improvements required for the Firemain and Auxiliary Machinery Cooling Water Systems are grouped as follows:

- Baseline Overhaul (BOH) Requirements
- Intracycle Maintenance Requirements

- Follow-On ROH Requirements
- Reliability and Maintainability Improvements
- Planned Maintenance System Changes
- Industrial Facility Improvements
- IMA Improvements
- Integrated Logistic Support (ILS) Improvements

Table 4-1 summarizes all recommendations resulting from this Review of Experience. A detailed listing of recommended PMS changes is included in the DDEOC MRC Evaluation Table of Appendix E. Action items resulting from these recommendations are listed in the DDEOC Action Table of Appendix F.

Table 4-1. SUMMARY OF ROE RECOMMENDATIONS		
Equipment	**Recommendation**	**Reason**
Baseline Overhaul Requirements		
Engine Lathe	Inspect and repair as necessary. Ensure that all attachments are available.	Availability of a workable lathe is fundamental to the Ship's Force repair effort.
Firepump Turbine	Perform Class "B" overhaul of the turbines in accordance with TRS 0521-086-601.	This type of overhaul should be accomplished only at the depot level.
Intracycle Maintenance Requirements		
All equipments of the Firemain and Auxiliary Machinery Cooling Water Systems	Accomplish existing PMS requirements as modified by recommendations of this report.	Existing PMS requirements, modified as recommended by this report, adequately address required intracycle maintenance.
Follow-On ROH Requirements		
Engine Lathe	Inspect and repair as necessary.	Availability of a workable lathe is fundamental to the Ship's Force repair effort.
Firepump Turbines	Perform Class "B" overhaul of the turbines in accordance with TRS 0521-086-601.	Estimated to be necessary by the end of a 60-month operating cycle.
Reliability and Maintainability Improvements		
Motor and Turbine Driven Firepumps	TYCOM should establish a uniform firepump operating policy to: • Operate firepumps 2 and 4 whenever steam is available. • Operate firepumps 1 and 6 in port or when under way when firepumps 2 and 4 are not available. • Keep firepumps 3 and 5 set up for automatic start to the maximum extent possible.	Shift the relative maintenance burden from the high-burdened 3 and 5 to the lower-burdened 1 and 6, reduce the number of rewinds of 1 and 6, and increase the effectiveness of the automatic start capability of 3 and 5.
	NAVSEC should determine the best method for gun-metal pump casing repair and promulgate uniform repair instructions.	At least two different methods of repair are currently in use, no determination having been made of which method is preferred.
	Use a run-to-failure maintenance strategy for the installed firepumps of the DDG-37 Class.	The mean time between significant maintenance actions is short.
	Develop a ShipAlt to implement the recommended relocation of the firepump bearing housing vent drain.	Improved grease flow through the bearing.
	Develop a ShipAlt to install stainless steel casings on all DDG-37 Class firepumps.	Stainless steel casings provide a solution to the casing erosion problems, and firepumps 3 and 5 have more casing erosion problems than other firepumps.

(continued)

Table 4-1. (continued)		
Equipment	Recommendation	Reason
Reliability and Maintainability Improvements (continued)		
Firepump Electric Motors	Use a run-to-failure maintenance strategy for the installed firepump electric motors.	Motor-rewind prevention does not lend itself well to preventive maintenance based on calendar time.
	Develop a procedure to rewind the electric motors utilizing the sealed insulation system on all four electric-motor-driven firepumps.	The sealed insulation system, when implemented, promises to be an excellent long-term solution to the high rate of electric motor rewind for motors subjected to high-moisture environment.
Firepump Turbine	Use a run-to-failure maintenance strategy for the installed firepump turbines.	The intracycle maintenance should be minor, with major corrective maintenance being accomplished at SOH and follow-on ROHs.
Auxiliary Machinery Cooling Water Pump	Have Ship's Force check the flange-to-flange alignment of the pump and suction and discharge piping and adjust the pump foundation bolts and the piping hangers to correct any misalignment. The check should be made each time this pump is opened for corrective maintenance.	Reduce the internal wearing parts and motor bearing usage rates.
	Use a run-to-failure maintenance strategy for the installed auxiliary machinery cooling water pumps.	The mean time between significant maintenance actions is short.
	Develop a ShipAlt to provide a mechanical seal for the pump.	Decrease the number of motor rewinds.
Auxiliary Machinery Cooling Water Pump Motor	Construct a shield of light sheet metal over the motor.	Prevent grounding out of the motor due to accidental wetting.
	Develop a procedure to rewind the electric motors utilizing the sealed insulation system on both motors.	The sealed insulation system, when implemented, promises to be an excellent long-term solution to the high rate of electric motor rewind for motors subjected to high-moisture environments.
	Planned Maintenance System Changes	
Motor and Turbine Driven Firepumps	Change the periodicity of the annual open and inspect PMS check to a situation requirement.	The pump internals will be inspected when opened for corrective maintenance.
Motor Driven Firepumps	Establish a PMS requirement to operate firepumps 1 and 6 every day for about one hour.	Moisture accumulation will be prevented and the number of motor rewinds reduced.

(continued)

Table 4-1. (continued)		
Equipment	**Recommendation**	**Reason**
	Planned Maintenance System Changes (continued)	
Swing Check Valve	Establish a monthly PMS requirement to open and inspect firepump swing check valves on turbine driven firepumps.	Failure of the swing check valve usually results in serious damage to the motor or turbine.
Auxiliary Machinery Cooling Water Pumps	Change the periodicity of the annual open and inspect PMS check to a situation requirement.	The pump internals will be inspected when opened for corrective maintenance.
	Industrial Facility Improvements	
	None	
	IMA Improvements	
	None	
	Integrated Logistic Support (ILS) Requirements	
Engine Lathe	Have individual ships take the necessary steps to ensure that the assigned lathe operators are qualified in the operation and maintenance of the equipment.	A workable lathe with a qualified operator is fundamental to the Ship's Force repair effort.
	Provide DDG-39 with a lathe capable of accommodating the impeller diameter of the largest installed centrifugal pump.	A lathe with a minimum 10" swing is required.
Centrifugal Pump	Provide Ship's Force with a suitable Centrifugal Pump Repair Manual.	The organizational level maintenance effort will be improved.
	Provide suitable ball bearing heater ovens.	Ball bearing removal and reinstallation procedures will be standardized.
Motor and Turbine Driven Firepump	Provide APL 016021445 to all ships with stainless steel pumps and ensure that shipboard allowances for spare parts are adequate.	Ship visits indicated that ships with stainless steel pumps did not have the correct APLs.
	Change the material requirements for the impeller wearing rings of the firepumps supported by APL 016020494 from Stainless Steel class 303 to monel, QQ-N-288, composition B or D.	Currently stocked impeller wearing ring is not suitable for salt water applications.
	Assign an NSN to the monel impeller wearing ring, and revise APL 016020494 accordingly.	A monel impeller wearing ring will be less subject to corrosion than the currently stocked stainless steel one.
Firepump Swing Check Valve	Conduct a COSAL validation to ensure that the installed firepump swing check valves are supported by the proper APL.	Present COSALs do not always include the installed swing check valves.
Auxiliary Machinery Cooling Water Pump	Add NSN 9C-4320-00-541-8843, impeller wearing ring, to APL 016110076, with an allowance for two on-board spares.	The impeller wearing ring is not listed on the APL for the pump.

SOURCES OF INFORMATION

The specific sources of information used as a basis for the System Maintenance Analysis of the Firemain and Auxiliary Machinery Cooling Water Systems are listed below:

1. Generation IV MDS Part and Maintenance Data for DDG-37 Class for the period 1 January 1970 through 31 October 1976.

2. CASREP narrative summaries for the period 1 July 1973 to 30 June 1976.

3. Technical Manual - Turbine and Motor-Driven 500 G.P.M. Fire Pumps, Warren Pumps, Inc., NAVSHIPS 347-3242, (February 1959).

4. Ship Information Book, DLG-9 (DDG-40):
   - Volume 1, Hull and Mechanical, NAVSHIPS 0905-475-4010.
   - Volume 2, Part 1 of 2, Piping, NAVSHIPS 0905-475-4020.
   - Volume 2, Part 2 of 2, Piping, NAVSHIPS 0905-475-4030.

5. Propulsion Operating Guide for DDG-6, 7, 8, and 45.

6. Type Commander's COSAL, SURFLANT and SURFPAC, dated 28 April 1976 and 23 June 1976, respectively.

7. Allowance Parts Lists (APLs) for selected components of the Firemain and Auxiliary Machinery Cooling Water Systems.

8. Maintenance Index Pages and Maintenance Requirement Cards for selected components of the Firemain and Auxiliary Machinery Cooling Water Systems.

9. Technical Repair Standards (TRS):
   - TRS 0521-086-600, Pump, Fire (Turbine and Motor Driven)
   - TRS 0521-086-601, Turbine, Fire Pump
   - TRS 0521-086-604A, Motor, Coupled, Horizontal Mounted, Fire (Turbine and Motor-Driven) Pump

10. Trip Report (21-23 September 1977); ARINC Research Corporation visit to:

- COMNAVSURFLANT
- USS PRATT (DDG-44)
- USS MACDONOUGH (DDG-39)
- USS DEWEY (DDG-45)
- USS PUGET SOUND (AD-38)
- SIMA, Charleston, South Carolina

11. Technical Manual - Electrical Machinery Repair, Volume I, Electric Motor Repairs, NAVSEA 0900-LP-060-2010.

12. PERA (CRUDES), PHILNAVSHIPYD, "Ship Alteration Information Manual, DDG-37 Class", 1 November 1976.

13. *Development of Equipment Behavior Measures for Selected Equipments in the Propulsion Plant of DDG-2 Class Ships*, ARINC Research Publication 1623-01-1-1347, December 1974.

14. OPNAVINST 4790.4, *Material Maintenance Management (3M) Manual*, Volumes I and II, June 1973.

15. DDG-37 Class Maintenance Critical Equipment List, ARINC Research Corporation, 30 April 1976.

16. Overhaul Departure Reports for DDG-37 Class Ships.

APPENDIX A

BOUNDARIES OF FIREMAIN AND AUXILIARY MACHINERY COOLING WATER SYSTEMS FOR DDG-37 CLASS SHIPS

The Firemain and Auxiliary Machinery Cooling Water Systems discussed in this report consist principally of the components listed in Table A-1. The table also lists APL numbers and APL quantities per ship. In developing this table, at attempt was made to resolve inconsistencies among Type Commander's COSAL and MDS reporting data, but all such inconsistencies could not be resolved. This configuration is the best estimate from all available data sources.

Figure A-1 is a graphic representation of a typical DDG-37 Class Firemain and Auxiliary Machinery Cooling Water System, including a line diagram of the two systems, the selected components of each system, their associated APLs, and the interface between the two systems.

Table A-1. COMPONENTS OF FIREMAIN AND AUXILIARY MACHINERY COOLING WATER SYSTEM FOR DDG-37 CLASS

Nomenclature	APL/CID	Quantities by Hull Number									
		DDG-37	DDG-38	DDG-39	DDG-40	DDG-41	DDG-42	DDG-43	DDG-44	DDG-45	DDG-46
Firemain System											
Firepump, 500 GPM	016020494*	6	6	6	6	6	6	6	5	6	6
Firepump, 500 GPM	016021445*		1	1	1		1		2		2
Firepump, 500 GPM	016020528*								1		
Firepump Motor	174750564*	4	4	4	4	4	4	4	4	4	4
Controller (Firepump Motor 6)	151801406*	1	1	1	1	1	1	1	1	1	1
Controller (Firepump Motors 3 and 5)	151801533*										
Controller (Firepump Motor 1)	151801534*	1	1	1	1	1	1	1	1	1	1
Firepump Turbine	057950042*	2	2	2	2	2	2	2	[illegible]	2	2
Firepump Turbine Regulator	882260195*	2	2	2	2	2	2	2	2		2
Firepump Turbine Regulator	882260469*									2	
Flexible Coupling	782350005*	6	6	6	6	6	6	6	6	6	6
4.0" IPS Gate Valve	882042019	Precise configuration data unavailable.									
5.0" IPS Gate Valve	882042020**										
4.0" IPS Swing Check Valve	882035712										
4.0" IPS Swing Check Valve	882033714										
4.0" IPS Swing Check Valve	882032466										
4.0" IPS Swing Check Valve	882031321										
Auxiliary Machinery Cooling Water System											
Auxiliary Machinery Cooling Water Pump	016110076†	2	2	2	2	2	2	2	2	2	2
Auxiliary Machinery Cooling Water Pump	174750217†	[illegible]	2	2	2	2	2	2	2	2	2
3.5" IPS Reducing Valve	882091721	2	2	2	2	2	2	2	2	2	2
3.5" IPS Relief Valve	992117196	4	4	4	4	4	4	4	4	4	4
3.0" IPS Gate Valve	882042017	Precise configuration data unavailable									
3.5" IPS Gate Valve	882042018										

*NAVSHIPS Technical Manual 347-3242.
**Installed in Auxiliary Machinery Cooling Water System also.
†NAVSHIPS Technical Manual 347-3448.

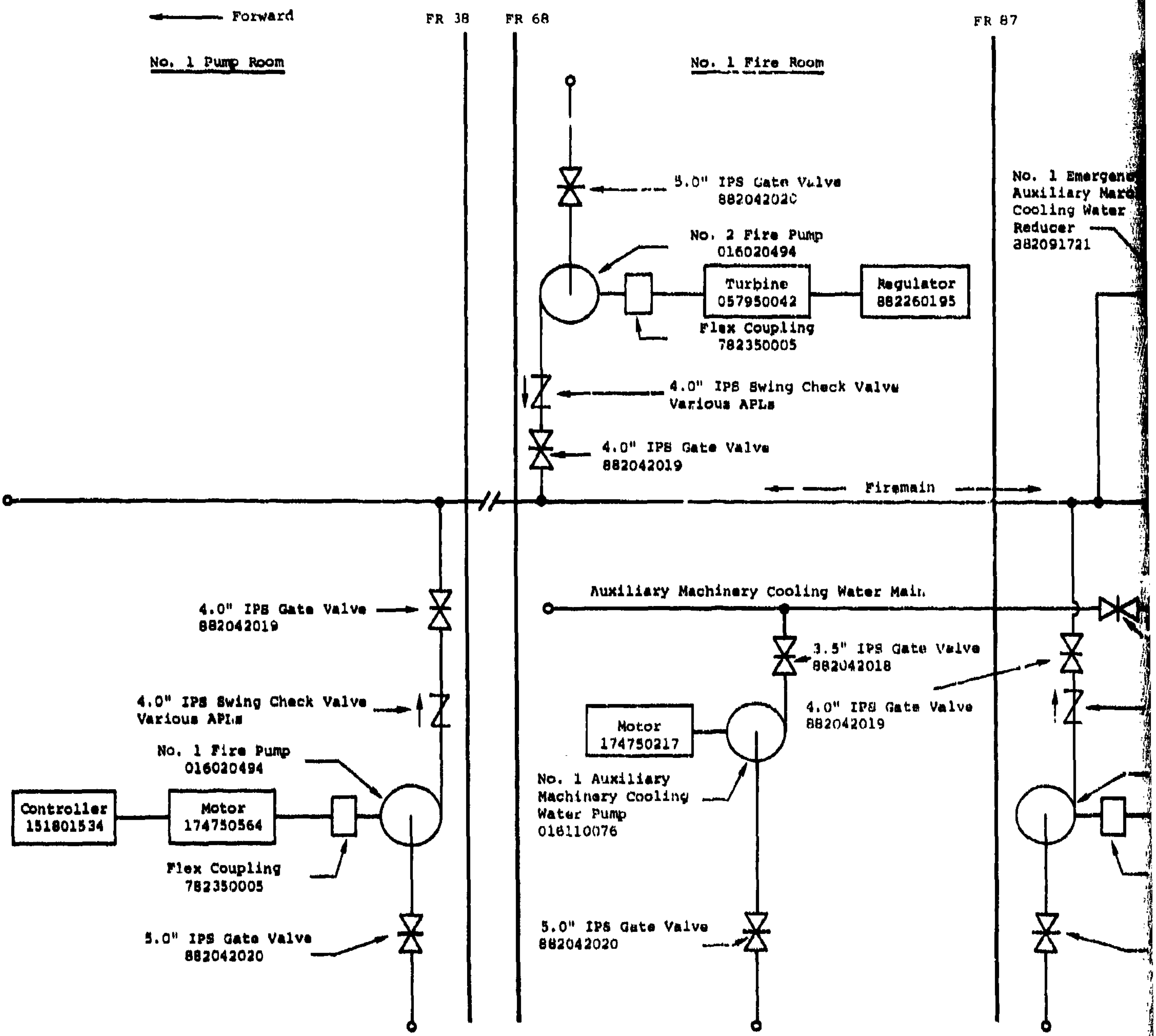


Figure A-1. TYP

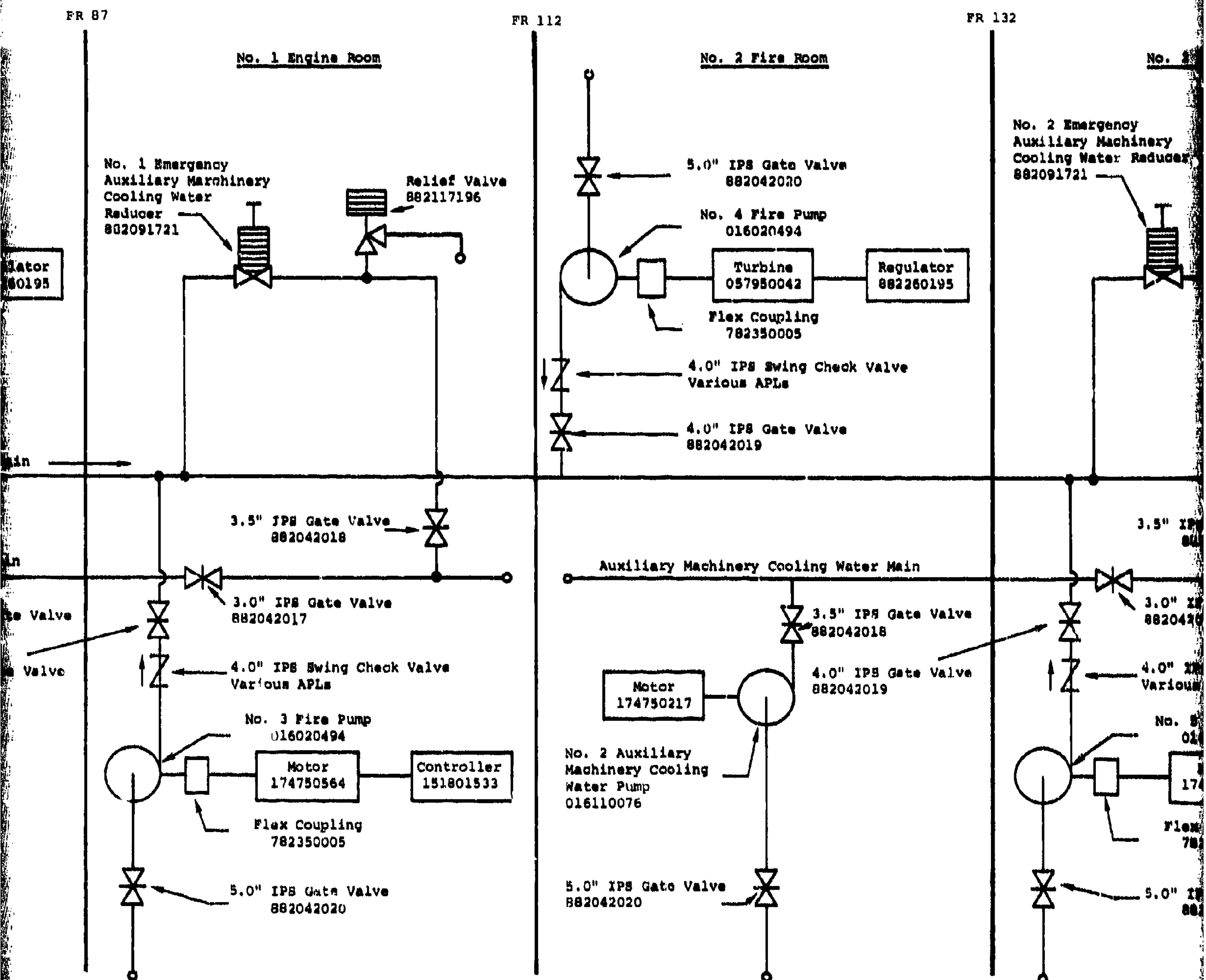
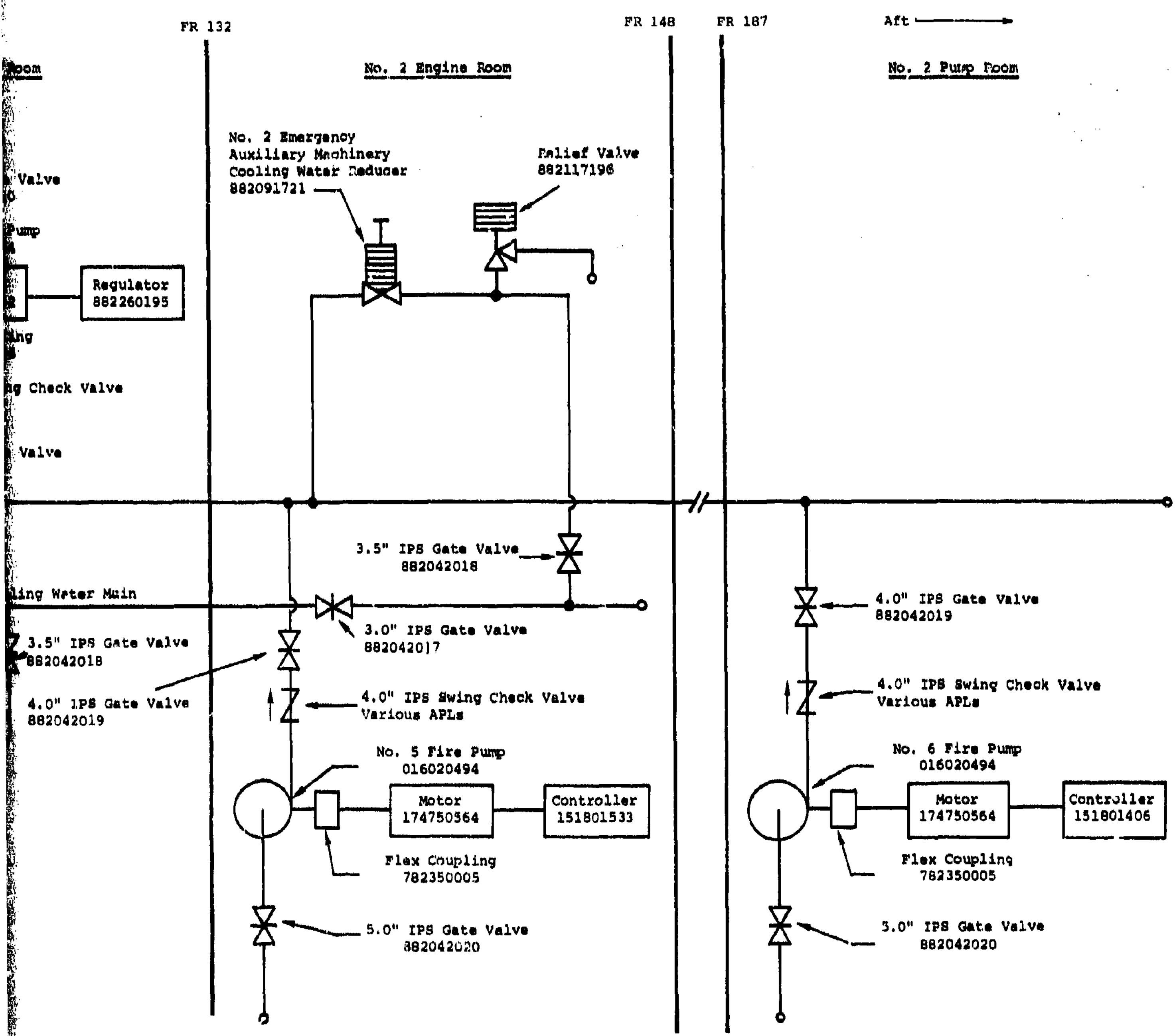


Figure A-1. TYPICAL DDG-37 CLASS FIREMAIN AND AUXILIARY MACHINERY COOLING WATER SYSTEMS



OOLING WATER SYSTEMS

APPENDIX B

CASREP SUMMARY

CASREPs for the DDG-37 Class Firemain System covering the period from 1 July 1973 to 30 June 1976 are shown in Table B-1. The CASREPs are listed by component and categorized by cause. The table is based on 56 CASREPs submitted by 10 ships that operated for a total of 20.9 ship operating years during this three-year period. Therefore, the rate of CASREP submission against the Firemain System for this period is:

$$\frac{\text{56 CASREPs}}{\text{20.9 Ship Operating Years}} = \text{2.68 CASREPs Per Ship Operating Year}$$

No CASREPTs were reported against the Auxiliary Machinery Cooling Water System during the CASREP data period.

Table B-1. CASREP ANALYSIS SUMMARY FOR THE DDG-37 CLASS FIREMAIN SYSTEM

Reason for CASREP	Number of CASREPs		Percent of Total CASREPs	Number of Ships Reporting
Firepump				8
Wear	12			
Part Failure	5			
Abnormal Environment	1			
Subtotal		18	32.1	
Firepump Turbine				3
Wear	2			
Part Failure	3			
Subtotal		5	8.9	
Firepump Motor				8
Part Failure	14			
Abnormal Environment	8			
Miscellaneous	4			
Subtotal		26	46.4	
Firepump Turbine Pressure Regulator				1
Wear	1			
Subtotal		1	1.8	
Flexible Coupling				2
Part Failure	1			
Abnormal Environment	1			
Subtotal		2	3.6	
Valves				2
Part Failure	2			
Miscellaneous	1			
Subtotal		3	5.4	
Electric Motor Controllers				1
Part Failure	1			
Subtotal		1	1.8	
Total		56	100.0	-

APPENDIX C

SUMMARY OF MIL-P-1739 (D) (SHIPS) DATED 13 MARCH 1972

The military specifications for centrifugal pumps suitable for use as fire pumps are contained in MIP-P-1739 (D) of 13 March 1972.

The existing DDG-37 Class firepumps, APL 016020494, were built to conform to MIL-P-1739 for Class C-2 pumps (C-2 representing pumps with an impeller between bearings). The significant differences are shown in Table C-1.

Table C-1. PART MATERIAL DIFFERENCES

Parts \ Application Category	MIL-P-1739 - original specification to which pump was built.	MIL-P-1739D dated 13 March 1972 - most recent specification to which new pumps are built.	Existing repair parts in the supply system for repairs to pumps built to MIL-P-1739. (Original cast gun-metal casings.)	Recommended repair parts for repair of pumps built to MIL-P-1739.
	Material			
1. Casing	Gun Metal	Stainless Steel	Gun Metal	Gun Metal
2. Impeller	Monel	Stainless Steel	Monel	Monel
3. Casing Wearing Rings	Bronze	Monel	Monel	Monel
4. Impeller Wearing Rings	Gun Metal	N/A*	Stainless Steel	Monel
5. Shaft	Rolled Monel	Rolled Monel	Rolled Monel	Rolled Monel
6. Shaft Sleeves	Nickel-Copper-Aluminum**	Nickel-Copper-Aluminum**	Nickel-Copper-Aluminum**	Nickel-Copper-Aluminum**
7. Shaft Seal	1/2" Braided Packing†	Mechanical Seal	1/2" Braided Packing†	1/2" Braided Packing†

*Impellers shall not be furnished with wearing rings. The impeller wearing hub shall have sufficient material thickness to function as would a wearing ring.
**Sleeves shall be made of nickel-copper-aluminum alloy or highly alloyed stainless steel.
†1/2" Teflon impregnated braided asbestos packing commonly used.

APPENDIX D

DATA ON SIGNIFICANT MAINTENANCE ACTIONS USED TO CREATE WEIBULL HAZARD PLOTS

The time in months between significant maintenance actions on firepumps (pump ends), firepump drivers, and auxiliary machinery cooling water pumps (pumps and drivers) was recorded for each ship. Each significant maintenance action was considered to restore the equipment to a like-new condition, and time was reset to zero following such an action. If the period of life did not end in a significant maintenance action but stopped at a conversion, ROH, or the end of the data period, the time was treated as a censored observation. The following illustration shows the difference between these two types of data:

Significant Maintenance Actions

Conversion or ROH	X months Time to Action	Y months Censored Observation	Conversion or ROH or End of Data

Both types of data were used in Nelson's hazard plotting method* to determine the parameters of the Weibull distribution which best fit the data.

In the tables that follow, censored observations are marked with an asterisk. Data for the six firepumps and drivers are given in Tables D-1 and D-2, respectively. Table D-3 contains data on the Auxiliary Machinery Cooling Water System pumps and motors.

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*"Hazard Plotting for Incomplete Failure Data", W. Nelson, *Journal of Quality Technology*, No. 1, pp 27-52, 1969.

Table D-1. MONTHS BETWEEN SIGNIFICANT MAINTENANCE ACTIONS FOR FIREPUMPS (PUMP ENDS)

Pump 1	Pump 2	Pump 3	Pump 4	Pump 5	Pump 6
2,2,2*	1,1*	1*,1*,1*,1*	1*	2,2,2,2	2
3*	3,3	2,2,2	2,2,2	2,2*	3,3,3,3*
4,4,4*	4,4,4,4,4*	3,3,3,3,3	3	3,3,3,3	4*
6,6,6,6*,6*	5,5	3,3,3*	4,4,4,4*	3,3*	5,5
7,7*	6,6,6*	4,4,4,4	5,5*,5*	4,4,4,4	6,6*
9,9*	7,7*,7*	4,4,4,4	6,6,6*	4,4,4,4	7*
10	8,8,8*,8*	4,4*	8	5,5,5,5	8*
11*	9	5,5,5,5	9,9	5,5*	9,9*
12	10	5*	10,10	6,6,6*	10
13	11	6,6*,6*	11,11	7*,7*	11,11*,11*
14*	12*,12*	7,7,7	12	8,8	12,12
15,15*	13	8,8,8,8*	14	9,9,9,9	13*
16	14,14,14	9,9,9,9	15*	9,9	14,14*
17,17*	15	10,10,10,10	17*	10,10	15
18,18*	16	11,11*	18*,18*	11	16
19*	17,17*	12,12	19,19*	13,13	17
21	18*,18*	13,13	21*	14,14,14	19
22	19*	14,14	22	14,14*	20*
23	21,21,21,21	15,15,15	23,23*	15	21*
25	27*	16	25,25*	16,16*,16*	22
26*	28	17,17*	27*	17	23
28	32	18	28	19,19*	27
30	36	22,22*	29*	21*	31*
34,34		31*	47*	33	35,35
45			50*	35	38
					45*

*Denotes censored observation.

Table D-2. MONTHS BETWEEN SIGNIFICANT MAINTENANCE ACTIONS FOR FIREPUMP DRIVERS

Motor 1	Turbine 2	Motor 3	Turbine 4	Motor 5	Motor 6
1	2	1*	3*	3	2,2,2*,2*
2,2	4,4,4	3	4,4,4,4*	4*,4*	2*
3,3*,3*,3*	5,5*	4,4,4,4	6	5*	3,3,3
4,4,4,4	6*	6*	8*	6	4,4,4,4*
5,5*	7*	7*	15*	7*	4*,4*,4*
6,6,6*,6*	9*	8,8*	16,16,16*	8	5,5,5
7,7,7,7*	11*	9,9*	17*	10,10*	6
8	12	14	18	12*	7
9,9,9	14*,14*	15*	19*	14*	8,8,8
13,13*	15	17,17*	20	16*	9
14,14*	16	18*	23,23*	18,18*	10,10,10
19*	17,17,17*	22,22*,22*	24	20*	11,11*
20	18,18*	23,23*	25	21*	14
23	19,19	25	27*	24	15
26*	20*	28*	31,31*	27	17*,17*
31	21*	39	33	28*	18
34	25,25	42	36*	29	21*,21*
35	27*	43*	39	31*	25
37*	30*	55*	43*	36*	27*,27*
38*	35	58*		39	36
39*	36*			45	37
41	43*			46*	38
49*	48*			56*	43*

*Denotes censored observation.

Table D-3. MONTHS BETWEEN SIGNIFICANT MAINTENANCE ACTIONS FOR AUXILIARY MACHINERY COOLING WATER SYSTEM

Unit 1		Unit 2	
Pump	Motor	Pump	Motor
1*	1*	1*	1,1,1,1,1,1,1*
2,2,2*	2,2,2,2,2	3,3,3*,3*	2,2,2,2,2*
3,3*	3,3,3,3*	4,4,4,4*,4*	3,3*,3*
4,4,4,4*	3*,3*	5,5,5	4,4,4,4
5	4,4,4,4	6,6*,6*	4,4,4
6*	5	7*,7*	5,5,5*
7*	6,6*	8	6,6*
8,8,8*	7,7,7*,7*	9	7,7,7,7,7,7*
9,9*	8,8*,8*	10,10	8*,8*
10,10,10*	10,10,10,10*	11	9,9
11,11	12	12	10,10,10
12	13,13,13	13,13,13	11,11,11*
15	18*	14*	12
16*	19,19,19	15,15*	13,13*,13*
17,17	20	16	14*
22,22*	21,21,21*	18	15,15
23,23*	23	22	16
27,27,27*	24	24	17
32	27	25*	22,22
51	28	26*	23,23*
		27,27	24,24*
		30	27
		38*	
		39	
		41*	

*Denotes censored observation.

APPENDIX E

MRC EVALUATION

The DDEOC MRC Evaluation form in this appendix specifies the Maintenance Index Pages (MIPs) applicable to the Firemain and Auxiliary Machinery Cooling Water System and lists the Maintenance Requirements Cards (MRCs) that should be modified or deleted, and indicates where new MRCs are needed:

- MRC Title - Description of maintenance specified by MRC
- MRC Number - Identification number of MRC
- Responsibility - Organizations responsible for change (if any)
- Current Status (self-explanatory)
- Man-Hours - Personnel time burden allotted to complete maintenance action
- Frequency - When the MRC maintenance action is to be performed, e.g., D = daily, W = weekly, M = monthly, Q = quarterly, S = semiannually, A = annually, C = once every cycle, R = as required
- Type - Perform maintenance (P), or survey material condition of components (S)
- Who Performs Test - Maintenance action or test to be performed by tender, or DDEOC site team, or Ship's Force personnel
- Where performed (self-explanatory)
- Data - Indicates whether data are recorded during performance of maintenance action

DDEOC MRC EVALUA

MRC TITLE	MRC NUMBER	RESPONSIBILITY		CURRENT STATUS			MAN-HOURS		FREQU	
		NAVSEA	DDEOC	OLD WITH NO CHANGE	OLD WITH REVISION	NEW	PRE-DDEOC M/H	POST-DDEOC M/H	PRE-DDEOC	P
ELECTRIC MOTOR DRIVEN FIREPUMP (MIP E-28/252)										
1. Inspect internal parts.	C3-C91K	X			X		8.0	16.0	A	
2. Operate #1 and #6 firepumps for approximately one hour.	TBD**	X				X	-	2.0	-	
TURBINE DRIVEN FIREPUMP (MIP E-37/51)										
1. Inspect internal parts	55-G81Q-N	X			X		16.0	-	A	
2. Open and inspect the firepump discharge swing check valve.	TBD**	X				X	-	4.0	-	
AUXILIARY MACHINERY COOLING WATER PUMP (MIP A-19/150)										
1. Inspect internal parts.	21-A13-CA	X			X		5.0	10.0	A	

*P = Perform Maintenance; S = Survey Inspection
** TBD - To Be Determined

SHIP CLASS: DDG-37

SMA NO: 37-201-521

SYSTEM: Firemain & Auxiliary Machinery Cooling Water Systems

MRC EVALUATION

HOURS	FREQUENCY		TYPE*	WHO PERFORMS TEST			WHERE PERFORMED	DATA	REMARKS
POST-DDEOC M/H	PRE-DDEOC	POST-DDEOC	P-PERF. S-SURV.	TENDER	DDEOC	SHIP	I-IN PORT S-AT SEA	YES NO	
16.0	A	R	P,S			X	I,S	Yes	Change periodicity to a situation requirement and accomplish when pump is opened for significant corrective maintenance.
2.0	-	D	P			X	I,S	No	Develop an MRC to require operation of #1 and #6 firepumps for approximately one hour daily to dry out the motor windings.
-	A	R	P,S			X	I,S	Yes	Change periodicity to a situation requirement and accomplish when pump is opened for significant corrective maintenance.
4.0	-	M	P,S			X	I,S	No	Develop an MRC to require the monthly opening and inspection of the firepump discharge swing check valve.
10.0	A	R	P,S			X	I,S	Yes	Change periodicity to a situation requirement and accomplish when the pump is opened for significant corrective maintenance.

2

APPENDIX F

DDEOC ACTION TABLE

DDEOC action items are presented in the table of this appendix. The table is formatted to provide the implementation status of changes through completion of the Class Maintenance Plan and to serve as a ready reference to specific sections in Chapter Three that address in detail the problem involved.

DDEOC ACTION TAB

1 ACTION ITEM* a. NO.	b. TITLE	2 DDEOC EVALUATION**	3 ACTION ITEM DESCRIPTION	4 REPORT REFERENCE (PARA.)	5
1.	BASELINE OVERHAUL REQUIREMENTS				
	Engine Lathe		Inspect and repair as necessary, insure all attachments are available.	3.1.1.1	N
	Firepump Turbine		Class "B" overhaul the turbine IAW TRS 0521-086-601.	3.2.4.7	NA
2.	INTRACYCLE MAINTENANCE REQUIREMENTS				
			No additional action required.		
3.	FOLLOW-ON ROH REQUIREMENTS				
	Engine Lathe		Inspect and repair as necessary, insure all attachments are available.	3.1.1.1	NA
	Firepump Turbine		Class "B" overhaul the turbine IAW TRS 0521-086-601.	3.2.4.7	NA
4.	RELIABILITY AND MAINTAIN-ABILITY IMPROVEMENTS				
	Motor and Turbine Driven Firepumps		Establish a uniform firepump operating policy to: • Operate firepumps 3 and 5 whenever steam is available. • Operate firepumps 1 and 6 in port or when under way when firepumps 2 and 4 are not available. • Keep firepumps 3 and 5 set up for automatic start to the maximum extent possible.	3.2.2.1 and 3.2.3.3	TY
			NAVSEC should determine the best method for gun metal pump casing repair.	3.2.2.5	NA

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATION

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: DDG-37

SMA NO: 37-201-521

SYSTEM: Firemain and Auxiliary Machinery Cooling Water Systems

OC ACTION TABLE

REPORT REFERENCE (PARA.)	RESPONSIBILITY †	SCHEDULING DATES REQD.	SCHEDULING DATES START	SCHEDULING DATES COMP.	REMARKS, FUNDING IMPLICATIONS, ETC.	ACTUAL ACTION TAKEN
3.1.1.1	NAVSEA 934X					
3.2.4.7	NAVSEA 934X					
3.1.1.1	NAVSEA 934X					
3.2.4.7	NAVSEA 934X					
3.2.2.1 and 3.3.3.3	TYCOM					
3.2.2.5	NAVSEC					

OR CONTINUATION OF DEVELOPING ACTIVITY TASK, 7, AS NECESSARY.

DDEOC ACTION TAB

1. ACTION ITEM* a. NO.	b. TITLE	2. DDEOC EVALUATION**	3. ACTION ITEM DESCRIPTION	4. REPORT REFERENCE (PARA.)	5.
4.	RELIABILITY AND MAINTAINABILITY IMPROVEMENTS (continued)				
	Motor and Turbine Driven Firepumps (continued)		A run-to-failure maintenance strategy is recommended.	3.2.2.8	N
			Develop a ShipAlt to implement the recommended firepump bearing housing vent drain relocation.	3.2.2.4	N
			Develop a ShipAlt to install stainless steel casings on all DDG-37 Class firepumps.	3.2.2.5	N
	Firepump Electric Motors		A run-to-failure maintenance strategy is recommended.	3.2.3.7	N
			Develop a procedure to rewind firepump electric motors utilizing the sealed insulation system.	3.1.1.3 & 3.2.3.3	N
	Firepump Turbines		A run-to-failure maintenance strategy is recommended.	3.2.4.7	N
	Auxiliary Machinery Cooling Water Pump Motor		Construct a shield, of light sheet metal, over the motor.	3.3.2.3	Ship assis
	Auxiliary Machinery Cooling Water Pump		Check the flange to flange alignment between the suction and discharge piping and the pump, adjusting the pump motor foundation bolts and pipe hangers as necessary to correct any misalignment.	3.3.1.3	Ship assi DDEO Team
			A run-to-failure maintenance strategy is recommended.	3.3.1.5	N
			Develop a procedure to rewind auxiliary machinery cooling water pump motors utilizing the sealed insulation system.	3.3.2.3	N
			Develop a ShipAlt to provide a mechanical seal for the pump.	3.3.2.3	N

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATION

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: DDG-37

SMA NO: 37-201-521

SYSTEM: Firemain and Auxiliary Machinery Cooling Water Systems

C ACTION TABLE

4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES a. REQD.	b. START	c. COMP.	7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
3.2.2.8	NAVSEA					
3.2.2.4	NAVSEA					
3.2.2.5	NAVSEA					
3.2.3.7	NAVSEA					
3.1.1.3 & 3.2.3.3	NAVSEA					
3.2.4.7	NAVSEA					
3.3.2.3	Ship's Force assisted by IMA					
3.3.1.3	Ship's Force assisted by DDEOC Site Team					
3.3.1.5	NAVSEA					
3.3.2.3	NAVSEA					
3.3.2.3	NAVSEA					

2

†OR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

DDEOC ACTION TA

ACTION ITEM * a. NO.	ACTION ITEM * b. TITLE	2 DDEOC EVALUATION **	3 ACTION ITEM DESCRIPTION	4. REPORT REFERENCE (PARA.)	5.
5.	PLANNED MAINTENANCE SYSTEM CHANGES				
	Motor and Turbine Driven Firepumps		Change the periodicity of MRC C3-C91K of MIP E-28/253 and MRC 55-G81Q-N of MIP E-37/51 from annual (A) to situation requirement (R).	3.2.2.8	T
	Motor Driven Firepump		Establish a PMS requirement to operate firepumps 1 and 6 on a daily basis for about one hour.	3.2.3.3	N
	Swing Check Valve		Establish a monthly PMS requirement to open and inspect firepump swing check valves on turbine driven firepumps.	3.2.4.5	N
	Auxiliary Machinery Cooling Water Pumps		Change the periodicity of MRC 21-A13-CA of MIP A-19/150 from annual (A) to situation requirement (R).	3.3.1.5	T
6.	INDUSTRIAL FACILITY IMPROVEMENTS		None.		
7.	IMA IMPROVEMENTS		None.		
8.	INTEGRATED LOGISTIC SUPPORT (ILS) REQUIREMENTS				
	Engine Lathe		Insure that a qualified lathe operator is assigned to each ship.	3.1.1.1	BU
			Provide DDG-39 with a lathe with a 10" minimum swing.	3.1.1.1	NA
	All Centrifugal Pumps		Provide Ship's Force with a suitable Centrifugal Pump Repair Manual.	3.1.1.2	NA
			Provide suitable ball bearing heater ovens.	3.1.1.4	NA

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATION

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: DDG-37

SMA NO: 37-201-521

SYSTEM: Firemain and Auxiliary Machinery Cooling Water Systems

C ACTION TABLE

REPORT REFERENCE (PARA.)	RESPONSIBILITY †	SCHEDULING DATES			REMARKS, FUNDING IMPLICATIONS, ETC.	ACTUAL ACTION TAKEN
		REQD.	START	COMP.		
3.2.2.8	TYCOM					
3.2.3.3	NAVSEA 934X					
3.2.4.5	NAVSEA 934X					
3.3.1.5	TYCOM					
3.1.1.1	BUPERS					
3.1.1.1	NAVSEA 934X					
3.1.1.2	NAVSEA 934X					
3.1.1.4	NAVSEA 934X					

2

OR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

DDEOC ACTION TAB

1. ACTION ITEM* a. NO.	b. TITLE	2. DDEOC EVALUATION**	3. ACTION ITEM DESCRIPTION	4. REPORT REFERENCE (PARA.)	5.
8.	INTEGRATED LOGISTIC SUPPORT (ILS) REQUIREMENTS (continued)				
	Motor and Turbine Driven Firepumps		Provide APL 016021445 to all ships with stainless steel pumps and insure adequate shipboard allowances for spare parts.	3.2.1	NAV
			Change the material requirements for the impeller wearing rings of the firepumps supported by APL 016020494 from stainless steel, Class 303, to monel, QQ-N-288, composition B or D.	3.2.2.3	NAV
			Assign an NSN to the monel impeller wearing ring, and revise APL 016020494 accordingly.	3.2.2.3	NAV
	Firepump Swing Check Valve		Conduct a COSAL validation to insure that the installed firepump swing check valves are supported by the proper APL.	3.2.4.5	Sh
	Auxiliary Machinery Cooling Water Pump		Add NSN 9C 4320-00-541-8843, impeller wearing ring, to APL 016110076 with an allowance for two on-board spares.	3.3.1.3	NAV

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATION

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: DDG-37

SMA NO: 37-201-521

SYSTEM: Firemain and Auxiliary Machinery Cooling Water Systems

)C ACTION TABLE

REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES			7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
		a. REQD.	b. START	c. COMP.		
3.2.1	NAVSEA 934X					
3.2.2.3	NAVSEC					
3.2.2.3	NAVSUP					
3.2.4.5	Ship's Force					
3.3.1.3	NAVSUP					

)R CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.